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ARO Editorial Words

Dear readers, you are holding the eighth issue (Vol V, No 1) of ARO-The Scientific Journal of Koya University in your hand. Aro is publishing its 3rd issue as an internationally listed Scientific Journal in Kurdistan Region/Iraq. Notably, Aro has been accepted for indexing in the Emerging Sources Citation Index (ESCI), a new edition of Web of Science™ as of Feb 2016. Content in this index is under consideration by Thomson Reuters to be accepted in the Science Citation Index Expanded™ (SCIE). Aro's individual articles are currently listed by Thomson Reuters using articles unique DOI numbers which is a historical achievement for our academic community. Aro is starting its fifth year journey in leading the quality of regional scientific publications with global impact. The editorial team is determined to keep the path of such a mission and sustain Aro's future publications with reliable quality in mind.

Despite the ongoing regional economic downturn and war on terror which have had a great impact on scientific research activities and funding of the regional universities in general and Koya University in particular, Aro is continuing to receive great numbers of well-motivated quality papers which shows its steadily growing trust among researchers in the region, demanding the increased volume of publication. Nevertheless, Aro is finding more focus in applied sciences with research values in current regional issues having International impacts.

Aro was created with long-term visions of becoming accessible to all researchers in Kurdistan and beyond, and covering a wide range of scholarly disciplines in sciences. Aro aspires to become a channel for exchanging of scholarly research by establishing academic connections between scholars globally. Therefore, we are asking our wider academic community to join us in this endeavor.

Aro is a journal of original scientific research, global news, review paper, letters and commentary. The Aro Scientific Journal is a peer-reviewed, open access journal that publishes original research articles as well as review articles in areas of natural sciences and technology. In this issue you will have access to original research papers in variety of areas, such as Petroleum, Physics, Chemical Engineering, Biochemistry, Engineering and Materials Science.

The warm responses from researchers, academics and professionals in the last four years have made us to create a wider Editorial Board which serves the wider submitted scientific manuscripts. However, it is clear that having a dedicated and well organized editorial board for the journal is only one side of the coin. The other is the ability to attract submissions of quality research and scholarly work. We are thankful to all of those who put their trust in Aro and presented their original research work for publication in Vol V, No 1(2017) of the journal, as well as, our thanks are extended to the 12 peer-reviewers from the Universities worldwide for their efforts in reviewing and enabling this issue of Aro.

Your support and feedback are invited and appreciated.

Dilan M. Rostam
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Dilan M. Rostam, Salah I. Yahya, Shwan K. Rachid, Basim M. Fadhil, Fahmi F. Muhammad and Muhammed H. Zangana.
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A Novel Technique for Solving Multiobjective Fuzzy Linear Programming Problems

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Abstract–This **study considers multiobjective fuzzy linear programming (MFLP) problems in which the coefficients in the objective functions are triangular fuzzy numbers. The study proposing a new technique to transform MFLP problems into the equivalent single fuzzy linear programming problem and then solving it via linear ranking function using the simplex method, supported by numerical example.**

***Index Terms*—Triangular fuzzy numbers, Multiobjective fuzzy linear programming problems, Linear ranking function, Compromise solution.**

I. Introduction

A basic linear programming (LP) problem deals only with a single linear objective function subject to a linear constraint set, and the assumption that parameters are known with certainty. LP problems involving more than one possibly conflicting objective functions are called multiobjective linear programming (MLP) problems. Multiobjective fuzzy linear programming (MFLP) problems occur when the objective functions coefficients are fuzzy numbers (FNs).

Tanaka, et al. (1974a) first introduced fuzzy linear programming (FLP) problems, building on fuzzy environment presented by Bellman and Zadeh (1970). Zimmermann (1978) introduced the formulation of FLP problem and constructed a model of the problem also based on the fuzzy concepts of Bellman and Zadeh (1970). By the beginning of the current century, FLP problems have been used in broadly different real life problems (Iskander, 2002; Zhang, et al., 2005; Rong and Lahdelma, 2008; Chen and Ko, 2009; Peidro, et al., 2010; Hassanzadeh, et al., 2011).

Ebrahimnejad and Tavana (2014) classified FLP problems into five main groups based on findings of various researchers (Zimmermann, 1987; Luhandjula, 1989; Inuiguchi, et al., 1990; Buckley and Feuring, 2000; Hashemi, et al., 2006; Dehghan, et al., 2006; Allahviranloo, et al., 2008; Hosseinzadeh Lotfi, et al., 2009; Kumar, et al., 2011).

In a fully fuzzified LP problem where all the parameters and variables are FNs, Buckley, and Feuring (2000) changed the problem of maximizing an FN, the objective function's value into an MFLP problems. They proved that all undominated set to MFLP problems can be explored by fuzzy flexible programming.

An interactive fuzzy programming was proposed by Sakawa, et al. (2000) to solve MLP problems with fuzzy parameters. After defuzzifying the fuzzy goals of the decision makers (DMs), a satisfactory solution is derived efficiently by updating the satisfactory degrees of the DMs at the topmost levels with respectfulness stable satisfactory among all levels.

MFLP vector optimization problems of a fuzzy nature were considered by Cadenas and Verdegay (2000) who assumed that all the objective functions involved come from the same DM with FN coefficients and they can be defined by different DMs.

Stanciulescu, et al. (2003) formulated a multiobjective decision-making process in which the coefficients of the objective functions and the constraints are fuzzy as MFLP problems. Their method uses fuzzy decision variables with a joint membership function instead of crisp decision variables. The lower bound fuzzy decision variables set up the lower bounds of the decision variables and generalize to lower-upper bound fuzzy decision variables that in turn set up the upper bounds of the decision variables too. The Optimal solutions (OSs) of the problem and their method supply to the DM regions containing potential satisfactory solutions around the OSs.

Cadenas and Verdegay (2000) used a ranking function in dealing with MFLP problems, multiobjective mathematical programming problems, vector optimization programming (VOP) problems, and Fuzzy Multiobjective Optimization problems. Ganesan and Veeramani (2006) introduced FLP with symmetric trapezoidal fuzzy numbers and proposed to solve this kind of problems using ranking function for FNs, without converting the problem to crisp LP problem. In the study of MFLP model for supplier selection in supply chain (Amid, et al., 2006), an MFLP model was developed with vagueness, imprecision of the goals, constraints, and parameters in which the decision-making has been made difficult for such kind of problems (Mahdavi-Amiri and Nasseri, 2006).

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Wu (2008a) derived the optimality conditions for LP problems with fuzzy coefficients when considering the orderings of the set of all FNs and proposed two solution approaches. Nondominated solution was proposed in the MLP problem by naturally eliciting the optimality conditions. To solve MFLP problems, Wu (2008b) converted the problem into a VOP problem by employing the embedding proposition and using appropriate linear defuzzification functions.

In some MFLP models, both the objective functions and the constraints are fuzzy. Furthermore, the coefficients of the decision variables in the objective functions, constraints, and the right-hand sides of the constraints are assumed to be FNs with either triangular or trapezoidal membership functions. Iskander (2008) proposed to utilize possibilistic programming to transform such MFLP problems as previously modeled (Negi and Lee, 1993) into its equivalent crisp programming according to the author's modifications. Iskander (2002, 2008) used two main criteria with the same evaluation concept in MFLP: The global criterion method and the distance functions method.

Baky (2009) proposed fuzzy goal programming algorithm for solving decentralized MFLP problems in the form of bilevel programming problems to obtaining OS for the problem. In another paper, the researcher (Baky, 2010) presented two new algorithms to solve MFLP problems through the fuzzy goal programming approach.

Amid, et al. (2011) developed a weighted max–min method and used it to solve MFLP problems to help managers of supplier selection and allow them to assign the order quantities to each supplier based on supply chain strategies.

Gupta and Kumar (2012) studied Chiang's method (Chiang, 2005) and pointed out the shortcomings in the latter's method. Hence, they proposed a new method to overcome these weaknesses of the MFLP problems by representing all the parameters in the system as (λ, ρ) interval-valued FNs.

In their review paper, Hamadameen and Zainuddin (2013) focused on various kinds of MFLP problems. They discussed the main studies in the recent years comprehensively. They considered problems with fuzziness in both the objective functions and constraints and analyzed MFLP problems chronologically. They also described problem formulation and the various research methodologies in MFLP problems. In addition, they surveyed many transformation methods that have been used to convert MFLP problems into their corresponding equivalent deterministic MLP problems. Moreover, they also addressed OSs for the original problem in each study.

Luhandjula and Rangoaga (2014) presented a new approach in solving continuous optimization problems based on the nearest interval approximation operator for dealing with an MFLP problem. They established a Karush-Kuhn-Tucker (KKT) kind of pareto optimality conditions. There were two crucial algorithms in the proposed method; the first gave nearest interval approximation to a given FN, and the second provided KKT conditions to deliver a pareto OS.

In this study, we address the MFLP problems in which objective functions' coefficients are triangular fuzzy numbers (T_rFNs). The study utilizes a linear ranking function through simplex method, in addition a new method to transform the MFLP problems into single FLP problem and find a compromise solution for the original problem, in which consists in minimizing the sum of distances from the objective functions to predefined ideal values. This paper is organized as follows: Section 2 defines fuzzy concepts and algebra properties of T_rFNs. Section 3 addresses linear ranking functions and the comparison of FNs. In addition, it gives the mathematical formulation of the T_rFNs. Section 4 defines the mathematical formulation for FLP problem and MFLP problems. Section 5 addresses OS, simplex method, and compromise solution for MFLP problems. Solution algorithms are presented in Section 6. In Section 7, to illustrate the proposed method, a numerical example is solved. Conclusions are discussed in Section 8.

II. Preliminaries of Fuzzy Concepts

This study uses some of the concepts of fuzzy sets. We list here some definitions and properties.

A. Basic Definitions

Fuzzy set: Let X be the universal set. $\tilde{A}$ is called a fuzzy set in X if $\tilde{A}$ is a set of ordered pairs $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) \mid x \in X\}$; where $\mu_{\tilde{A}}(x)$ is the membership function of x ∈ $\tilde{A}$ (Sakawa, 1993). Note that the membership function of $\tilde{A}$ is a characteristic (indicator) function for $\tilde{A}$ and it shows to what degree $x \in \tilde{A}$.

α-level set: The α-level set of $\tilde{A}$ is the set $\tilde{A}_\alpha = \{x \in R | \mu_{\tilde{A}}(x) \geq \alpha\}$, where $\alpha \in [0,1]$. The lower and upper bounds of α-level set $\tilde{A}$ are finite numbers represented by inf $x \in \tilde{A}_\alpha$ and sup $x \in \tilde{A}_\alpha$, respectively (Wang, 1997; Sakawa, 1993; Yager and Filev, 1994).

Normal Fuzzy Set: The height of a fuzzy set is the largest membership value attained by any point. If the height of fuzzy set equals one, it is called a normal fuzzy set (Wang, 1997).

The core (modal): The core of a fuzzy set $\tilde{A}$ of X is the crisp subset of X consisting of all elements with membership grade one, or core $(\tilde{A}) = \{x | \tilde{A}(x) = 1 \text{ and } x \in X\}$ (Yager and File, 199).

The support: The support of a fuzzy set $\tilde{A}$ is a set of elements in X for which $\tilde{A}(x)$ is positive, that is, supp $\tilde{A} = \{x \in X | \mu_{\tilde{A}}(x) > 0\}$ (Wang, 1997; Sakawa, 1993).

Fuzzy convex set: A fuzzy set $\tilde{A}$ is convex if $\mu_{\tilde{A}}(\lambda x + (1-\lambda) y) \geq min\{\mu_{\tilde{A}}(x), \mu_{\tilde{A}}(y)\}, \forall x, y \in X \wedge \lambda \in [0,1]$ (Wang, 1997; Sakawa, 1993).

Convexity and fuzzy number (FN): A convex fuzzy set $\tilde{A}$ on $\Re$ is an FN if: one its membership function is piecewise continuous; two there exist three intervals $[a, b]$, $[b, c]$ and $[c, d]$ such that $\tilde{A}$ is increasing on $[a, b]$, equal to 1 on $[b, c]$, decreasing on $[c, d]$, and equal to 0 elsewhere $\forall a, b, c \in \mathbb{R}$ (Mahdavi-Amiri and Nasseri, 2006; Mahdavi-Amiri and Nasseri, 2007).

The trapezoidal fuzzy number (T_pFN): Let $\tilde{A} = (a^L, a^U, \alpha, \beta)$ be the T_pFN, where $[a^L, a^U]$ is the modal set of $\tilde{A}$, and

$[a^L - \alpha, a^U + \beta]$ its support part (Mahdavi-Amiri and Nasseri, 2006; Mahdavi-Amiri and Nasseri, 2007) (Fig. 1).

If $a = a^L = a^U \in \tilde{A}$ then the T_pFN is reduced to T_rFN and denoted by $\tilde{A} = (a, \alpha, \beta)$ (Fig. 2). Thus, $\tilde{A} = (a, \alpha, \beta) \subset (a^L, a^U, \alpha, \beta)$. Since the study is focused on MFLP problems with T_rFNs, the next section lists algebra properties specific to such FNs.

B. Algebra Properties of FNs

Let $\tilde{A}_1, \tilde{A}_2 \in$ TrFNs, such that $\tilde{A}_1 = (a_1, \alpha_1, \beta_1)$ and $\tilde{A}_2 = (a_2, \alpha_2, \beta_2)$, then based on Zadeh (1965), Dubois and Prade (1978), and Sakawa (1993) the following rules apply:

1. Addition: $\tilde{A}_1 \oplus \tilde{A}_2 = (a_1, \alpha_1, \beta_1) \oplus (a_2, \alpha_2, \beta_2) = (a_1 + a_2, a_1 + \alpha_1, \beta_1 + \beta_2)$
2. Image $\tilde{A}_1$ = Image $(a_1, \alpha_1, \beta_1) = -\tilde{A}_1 = -(a_1, \alpha_1, \beta_1) = (-a_1, \beta_1, \alpha_1)$
3. Subtraction: $\tilde{A}_1 \ominus \tilde{A}_2 = (a_1, \alpha_1, \beta_1) \ominus (a_2, \alpha_2, \beta_2) = (a_1, \alpha_1, \beta_1) \oplus (-a_2, \beta_2, \alpha_2) = (a_1 - a_2, \alpha_1 + \beta_2, \beta_{1+} \alpha_2)$
4. Multiplication: $\tilde{A}_1 \otimes \tilde{A}_2 =$

$$(a_1,\alpha_1,\beta_1)\otimes(a_2,\alpha_2,\beta_2) \cong \begin{Bmatrix} (a_1a_2,\ a_1\alpha_2 + a_2\alpha_1,\ a_1\beta_2 + a_2\beta_1); a_1 < \tilde{0}, a_2 > \tilde{0} \\ (a_1a_2,\ a_2\alpha_1 - a_1\beta_2,\ a_2\beta_1 - a_1\alpha_2); a_1 > \tilde{0}, a_2 < \tilde{0} \\ (a_1a_2, -a_2\beta_1 - a_1\beta_2, -a_2\alpha_1 - a_1\alpha_2); a_1 < \tilde{0}, a_2 < \tilde{0} \end{Bmatrix}$$

5. Scalar multiplication:

$$\delta \otimes \tilde{A}_1 = \delta \otimes (a_1,\alpha_1,\beta_1) = \begin{Bmatrix} (\delta a_1, \delta\alpha_1, \delta\beta_1);\ \delta > 0 \\ (\delta a_1, -\delta\beta_1, -\delta\alpha_1);\ \delta < 0 \end{Bmatrix}$$

6. Inverse: $\tilde{A}_1^{-1} = (a_1,\alpha_1,\beta_1)^{-1} = \left(a_1^{-1},\ \beta_1 a_1^{-2}, \alpha_1 a_1^{-2}\right)$

7. Division: $\dfrac{\tilde{A}_1}{\tilde{A}_2} = \dfrac{\tilde{A}_1}{\tilde{A}_2^{-1}} = \dfrac{a_1,\alpha_1,\beta_1}{a_2,\alpha_2,\beta_2}$.

$$= \left(\frac{a_1}{a_2}, \frac{\beta_2 a + \alpha_1 a_2}{a_2^2}, \frac{\alpha_2 a_1 + \beta_1 a_2}{a_2^2} \right); \forall \tilde{A}_1, \tilde{A}_2 > \tilde{0}$$

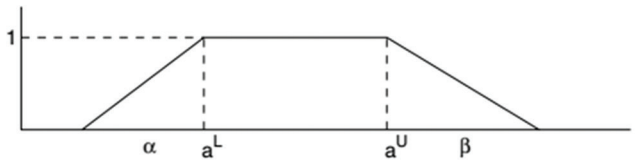

Fig. 1 Trapezoidal fuzzy number

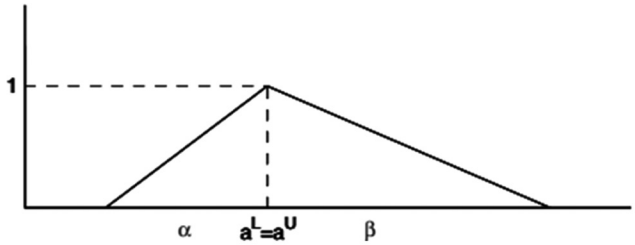

Fig. 2 Trinomial fuzzy number

Note that similar formulas hold when $\tilde{A}_1 < \tilde{0}, \tilde{A}_2 > \tilde{0}$ or $\tilde{A}_1 > \tilde{0}, \tilde{A}_2 < \tilde{0}$

8. $\tilde{A}_1 = \tilde{0} \Leftrightarrow \tilde{A}_1 = (0,0,0)$.

III. Ranking Functions and the Comparison of *FN*

The first step in solving MFLP is to defuzzify the fuzzy assertion. One of the several tools used to achieve this aim is a ranking function (Fang and Hu, 1996; Lai and Hwaang, 1992; Maleki,et al., 2000; Shoacheng, 1994; Tanaka, et al., 1974b; Maleki, 2003; Mahdavi-Amiri and Nasseri, 2006; Mahdavi-Amiri and Nasseri, 2007; Ebrahimnejad, 2011; Ullah Khan,et al., 2013) based on the comparison of the FNs (Wang and Kerre, 2001; Garcia-Aguado and Verdegay, 1993; Maleki, 2003).

This study focuses on a ranking function by Mahdavi-Amiri and Nasseri (2007). This ranking function is particularly suitable for T_pFNs. It transforms the FN to a real number. A ranking function $\Re : F(R) \to \mathbb{R}$ is a map which transforms each FN into its corresponding real line, where a natural order exists (Roubens and Jacques, 1991; Fortemps and Roubens, 1996; Mahdavi-Amiri and Nasseri, 2007; Nasseri, et al., 2005).

For an T_pFN $(\tilde{a}) = (a^L, a^U, \alpha, \beta)$, Yager (1981) proposed the special kind of $\Re(\tilde{a})$ formulated as follows:

$$\Re(\tilde{a}) = \frac{1}{2}\int_0^1 (inf\tilde{a}_\lambda + sup\tilde{a}_\lambda)\, d\lambda = \frac{a^L + a^U}{2} + \frac{\beta - \alpha}{4} \qquad (1)$$

Based on the definition of TrFN, and TpFN, (1) can convert into the following form for the TrFNs:

$$\Re(\tilde{a}) = a + \frac{\beta - \alpha}{4} \qquad (2)$$

In this study, we focus only on the linear ranking function. We list some of its properties on FNs.

For all $\tilde{a}_1, \tilde{a}_2, \tilde{a}_3, \tilde{a}_4 \in$ FNs, and $\delta \in \Re$ then:

i. $\tilde{a}_1 \geq_{\Re} \tilde{a}_2 \Leftrightarrow \Re(\tilde{a}_1) \geq \Re(\tilde{a}_2)$

ii. $\tilde{a}_1 >_{\Re} \tilde{a}_2 \Leftrightarrow \Re(\tilde{a}_1) > R(\tilde{a}_2)$

iii. $\tilde{a}_1 =_{\Re} \tilde{a}_2 \Leftrightarrow \Re(\tilde{a}_1) = \Re(\tilde{a}_2)$

iv. $\tilde{a}_1 \leq_{\Re} \tilde{a}_2 \Leftrightarrow \Re(\tilde{a}_1) \leq \Re(\tilde{a}_2)$

v. $\delta\tilde{a}_1 +_{\Re} \tilde{a}_2 = \delta\Re\tilde{a}_1 + \Re(\tilde{a}_2)$

vi. $\tilde{a}_1 =_{\Re} \tilde{0} \Leftrightarrow \Re(\tilde{a}_1) = \Re(\tilde{0}) = 0$

vii. $\tilde{a}_1 \geq_{\Re} \tilde{a}_2 \Leftrightarrow \tilde{a}_1 - \tilde{a}_2 \geq_{\Re} 0 \Leftrightarrow -\tilde{a}_2 \geq_{\Re} -\tilde{a}_1$

viii. $\tilde{a}_1 \geq_{\Re} \tilde{a}_2 \wedge \tilde{a}_3 \geq_{\Re} \tilde{a}_4 \Leftrightarrow \tilde{a}_1 + \tilde{a}_3 \geq_{\Re} \tilde{a}_2 + \tilde{a}_4$

IV. Problem Formulation

A. FLP Problem

The mathematical formulation of the FLP problem can be written as follows:

$$\begin{aligned} &Max\ \tilde{z}(x) =_{\Re} \tilde{c}x \\ &s.t. Ax \le b \\ &x \ge 0 \end{aligned} \quad (3)$$

Where $\tilde{c}^T$, A and b are of dimentions (n, 1), (m, n) and (m, 1), respectively. A feasible solution for (3) is the vector $x \in R^n$ which satisfies the constraints and their signs. In addition, x^* is an optimal feasible solution for (3) if and only if $\tilde{c}x^* \ge_{\Re} \tilde{c}x$, for all feasible solution x. On the other side of the constraints of (3), if Rank (A, b) = Rank (A) = m, then after partition and rearranging of the columns of $A = [B, N]$, where the nonsingular matrix $B = (m, m)$, and rank (B) = m where $x_B = B^{-1} b$, $x_N = 0$; then, the basic solution point $x\left(x_{B^T}, x_{N^T}\right)^T$ is called the basic feasible solution (BFS) for the system in (3), where $b$and $n$are basic matrix, and non-basic matrix, respectively (Nasseri, et al., 2005).

B. MFLP Problem

The mathematical formulation of the MFLP problems can be written as follows:

$$\begin{aligned} &Max\ \tilde{Z}_i(x) =_{\Re} \sum_{j=1}^{n} \tilde{c}_{ij}\ x_j; i = 1,\ldots,r \\ &Min\ \tilde{Z}_i(x) =_{\Re} \sum_{j=1}^{n} \tilde{c}_{ij} x_j; i = r+1,\ldots,s \\ &s.t. Ax \le b \\ &x \ge 0 \end{aligned} \quad (4)$$

Where $\tilde{c}^T$, A, b and x are as defined in (3).

V. Simplex Method and Feasible Solution for FLP Problem

For the FLP problem in (3), after converting it to the standard form:

$$\begin{aligned} &Max\tilde{z}(x) =_{\Re} \tilde{c}_B x + \tilde{c}_N s \\ &s.t. Bx_B + Ns_N = b \\ &x_B, s_N \ge 0 \end{aligned} \quad (5)$$

Since,

$$x_B + B^{-1}Ns_N = B^{-1}b,\ \tilde{z} + \left(\tilde{c}_B B^{-1}N - \tilde{c}_N\right)s_N =_{\Re} \tilde{c}B^{-1}b.$$

initially $s_N = 0$ thus, $x_B = B^{-1}b$, $\tilde{z} =_{\Re} \tilde{c}_B B^{-1}b$. We can express (3) in Table I.

In Table I, we have (Dantzig, 1963; Maleki, et al., 2000; Nasseri, et al., 2005; Mahdavi-Amiri and Nasseri, 2007; Sharma, 2012):

1. The fuzzy objective row, $\tilde{\gamma}_j =_{\Re} \left(\tilde{c}_B B^{-1} a_j - \tilde{c}_j\right)_{j \ne B_j}$ continuous the $\tilde{\gamma}_j =_{\Re} \tilde{z}_j - \tilde{c}_j$ for the nonbasic variables.
2. For the feasible OS, it should be $\tilde{\gamma}_j =_{\Re} \ge 0, \forall\ j \ne B_i$.
3. If, $\tilde{\gamma}_k <_{\Re} 0, \forall k \ne B_i$, then exchange x_{Br} by x_k. After that satisfying $\gamma_k =_{\Re} B^{-1}a_k$.
4. If, $\tilde{\gamma}_k \le_{\Re} 0$, then x_k is an unbounded solution for the problem.

TABLE I
The FLP Problem

	Objective function value: $\tilde{z}$	RHS	Basic variable: x_B	Nonbasic variable: S_N
x_B	0	1	$B^{-1}\ b$	$B^{-1}\ b$
$\tilde{z}$	1	$\tilde{c}_B B^{-1} b$	$\tilde{0}$	$\tilde{c}_B B^{-1} N - \tilde{c}N$

RHS: Right hand side, FLP: Fuzzy linear programming

5. If an m exist such that $\tilde{z}_m - \tilde{c}_m <_{\Re} \tilde{0}$ and there exist a basic index i in which $y_{im} > 0$, then a pivoting row p can be found in which the pivoting y_{pm} yields a feasible tableau corresponding fuzzy objective value.
6. For any feasible solution to FLP problem, there are some columns not in the basic solution in which $\tilde{z}_m - \tilde{c}_m <_{\Re} \tilde{0}$ and $y_{im} \le 0$, $i = 1,\ldots,s$ then the problem is unbounded.

VI. Compromise Solution

Since many objectives of the system usually conflict with each other, an improvement of one objective may mean the sacrifice in another. A compromise solution lets the DMs specify partial preferences among conflicting objectives so that there will be less alternative solutions. This can mean making adjustments to others.

A. A Compromise Solution for MFLP Problems

Since there may be conflicts among the multiple objectives in the MFLP problems in (4) under the same set of constraints, it is difficult to find a solution which satisfies all of those objective functions. Thus, a compromise solution is most realistic and practical for such kinds of the problems. The decision variable may not be common to all OSs in the presence of conflicts among objectives. However, the common set of decision variables between objective functions is necessary to facilitate selection of the best compromise solution. The next section summarized the solution algorithm for the method used in this study.

B. Solution Algorithms

Let us now describe the algorithm step by step:

Step 1: Consider the problem as the mathematical form in (4).

Step 2: Convert (4) into the standard form as:

$$\begin{aligned} &Max\ \tilde{Z}_i(x) =_{\Re} \sum_{j=1}^{n} (\tilde{c}_{ijB} x_j + \tilde{c}_{ijN} s_j); i = 1,\ldots,r \\ &Min\ \tilde{Z}_i(x) =_{\Re} \sum_{j=1}^{n} (\tilde{c}_{ijB} x_j + \tilde{c}_{ijN} s_j); i = r+1,\ldots,s \\ &s.t. Bx_B + Ns_N \le b \\ &x_B,\ s_N \ge 0 \end{aligned} \quad (6)$$

Step 3: Use the tableau notifications in Table I to solve each FLP problem in the form of (5) by simplex method.

Step 4: Assign $\tilde{v}_i$ to the optimum value of the objective function $\tilde{Z}_i; i = 1,\ldots,r,\ldots,s$.

Step 5: Convert (6) into its corresponding FLP problem as follows:

$$Max\ \tilde{Z}(x) =_{\Re} \sum_{j=1}^{n}[Max\ \tilde{c}_{ij}x_j \oslash \tilde{v}_i]_{i=1,\ldots,r}$$
$$-\sum_{j=1}^{n}[Max\ \tilde{c}_{ij}x_j \oslash \tilde{v}_i]_{i=r+1,\ldots s} : \forall \tilde{v}_i \neq \tilde{0}$$
$$s.t. Bx_B + Ns_N \leq b$$
$$x_B, s_N \geq 0 \quad (7)$$

Step 6: Find an OS for (7) which will give the compromise solution for the original problem in the (4).

VII. Numerical Example

Consider the following MFLP problems:

$$Max\ \tilde{Z}_1(x) =_{\Re} (5,2,5)x_1 + (6,3,6)x_2 + (5,3,7)x_3$$
$$Max\ \tilde{Z}_2(x) =_{\Re} (4,7,11)x_1 + (5,5,9)x_2 + (3,6,10)x_3$$
$$Min\ \tilde{Z}_3(x) =_{\Re} (-1,3,2)x_1 + (-3,4,1)x_2 + \left(\frac{-5}{2},9,7\right)x_3$$
$$Min\ \tilde{Z}_4(x) =_{\Re} (-3,4,4)x_1 + (-3,4,6)x_2 + (-3,4,8)x_3$$
$$s.t. 3x_1 - x_2 + 3x_3 \leq 7$$
$$-2x_1 + 4x_2 \leq 12$$
$$-4x_1 + 3x_2 + 8x_3 \leq 10$$
$$x_j \geq 0, j = 1,2,3 \quad (8)$$

Solution: First, we solve each objective function subject to the constraints individually, as:

$$Max\ \tilde{Z}_1(x) =_{\Re} (5,2,5)x_1 + (6,3,6)x_2 + (5,3,7)x_3 + \tilde{0}\sum_{j=1}^{3} s_j$$
$$s.t. 3x_1 - x_2 + 3x_3 + s_1 = 7$$
$$-2x_1 + 4x_2 + s_2 = 12$$
$$-4x_1 + 3x_2 + 8x_3 + s_3 = 10$$
$$x_j, x_j \geq 0, j = 1,2,3 \quad (9)$$

From Table II, we have $\left\{\left(\tilde{z}_j - \tilde{c}_j\right)\right\}$

$=_{\Re} \left\{(-5,5,2),(-6,6,3),(-5,7,3),\tilde{0},\tilde{0},\tilde{0}\right\}; j = 1,\ldots,6$.

j = 1.,6

Since, $\left\{\gamma_j\right\} = \left\{\Re\left(\tilde{\gamma}_j\right)\right\} = \left\{-5\frac{3}{4}, -6\frac{3}{4}, -6, 0, 0, 0\right\}$,

j = 1.,6, thus, x_2 should enter the basic solution, and the leaving variable s_2.

The result is as shown in Table III.

From Table III, we have

$$\left\{\left(\tilde{z}_j - \tilde{c}_j\right)\right\} =_{\Re} \left\{\left(-8,8,\frac{7}{2}\right),\tilde{0},(-5,7,3),\tilde{0},\left(\frac{3}{2},\frac{3}{4},\frac{3}{2}\right),\tilde{0}\right\};$$

j = 1.,6

TABLE II
The Status of the Solution-1

B	$\widetilde{ci}$	RRHS	(5,2,5)	(6,3,6)	(5,3,7)	$\tilde{0}$	$\tilde{0}$	$\tilde{0}$	Min ratio
			x_1	x_2	x_3	s_1	s_2	s_1	
s_1	$\tilde{0}$	7	3	−1	3	1	0	0	_
s_2	$\tilde{0}$	12	−2	4	0	0	1	0	3←
s_3	$\tilde{0}$	10	−4	3	8	0	0	1	$3\frac{1}{3}$
	$\tilde{z}$	$\tilde{0}$	(−5,5,2)	(−6,6,3) ↑	(−5,7,3)	$\tilde{0}$	$\tilde{0}\downarrow$	$\tilde{0}$	$\Re$

Table III
The Status of the Solution-2

B	$\widetilde{ci}$	RRHS	(5,2,7)	(6,3,6)	(5,3,7)	$\tilde{0}$	$\tilde{0}$	$\tilde{0}$	Min ratio
			x_1	x_2	x_3	s_1	s_2	s_1	
s_1	$\tilde{0}$	10	3	0	3	1	$\frac{1}{4}$	0	4←
s_2	(6, 3, 6)	3	−2	1	0	0	$\frac{1}{4}$	0	-
s_3	$\tilde{0}$	1	−4	0	8	0	$\frac{-3}{4}$	1	-
	$\tilde{z}(18,9,18)$		$\left(-8,8,\frac{7}{2}\right)\uparrow$	$\tilde{0}$	(-5,7,3)	$\tilde{0}\downarrow$	$\left(\frac{3}{2},\frac{3}{4},\frac{3}{2}\right)$	$\tilde{0}$	$\Re$

Since, $\left\{\gamma_j\right\} = \left\{\Re\left(\tilde{\gamma}_j\right)\right\} = \left\{-9\frac{1}{8}, 0, -6, 0, 1\frac{11}{16}, 0\right\}, j = 1,\ldots,6$.

Thus, x_1 should enter the basic solution and the leaving variable s_1. The result is as shown in Table IV.

Now,

$$\left\{\left(\tilde{z}_j - \tilde{c}_j\right)\right\} =_{\Re} \left\{\begin{matrix}\tilde{0},\tilde{0},(-5,7,3),\tilde{0},\left(\frac{23}{5},\frac{56}{5},\frac{63}{5}\right),\\ \left(\frac{16}{3},\frac{7}{3},\frac{16}{3}\right),\left(\frac{23}{10},\frac{11}{10},\frac{23}{10}\right),\tilde{0}\end{matrix}\right\}; j = 1,\ldots,6,$$

and

$$\left\{\gamma_j\right\} = \left\{\Re\left(\tilde{\gamma}_j\right)\right\} = \left\{0, 0, 4\frac{19}{20}, 6\frac{1}{12}, 2\frac{3}{5}, 0\right\} \geq 0, j = 1,\ldots,6.$$

Thus, according to the optimality feasible condition, no more variable can be found to enter the basis, and the OS for the problem (9) is;

$$\left\{\tilde{z}_1; X_1(x_1, x_2, x_3)\right\} = \left\{(50,23,50); X_1(4,5,0)\right\}.$$

Using the solution algorithm in Section 6, one can find the OSs for other $\tilde{z}_i; i = 2,\ldots,4$ as shown in Table V.

X_i (x_1, x_2, x_3)

Now, by utilizing (7), the result is a single FLP problem as follows:

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TABLE IV
THE STATUS OF THE SOLUTION-3

B	$\widetilde{ci}$	RRHS	(5, 2, 7)	(6, 3, 6)	(5, 3, 7)	$\tilde{0}$	$\tilde{0}$	$\tilde{0}$	Min ratio
			x_1	x_2	x_3	s_1	s_2	s_3	
x_1	(5,2,5)	4	1	0	$\frac{6}{5}$	$\frac{2}{5}$	$\frac{1}{10}$	0	
x_2	(6,3,6)	5	0	1	$\frac{3}{5}$	$\frac{1}{5}$	$\frac{3}{10}$	0	
s_3	$\tilde{0}$	11	0	0	11	1	$-\frac{1}{2}$	1	
	$\tilde{z}$	(50, 23, 50)	$\tilde{0}$	$\tilde{0}$	$\left(\frac{23}{5},\frac{56}{5},\frac{63}{5}\right)$	$\left(\frac{16}{3},\frac{7}{3},\frac{16}{3}\right)$	$\left(\frac{23}{10},\frac{11}{10},\frac{23}{10}\right)$	$\tilde{0}$	$\Re$

TABLE V
THE STATUS OF THE OBJECTIVE FUNCTIONS

Objective function$(\tilde{Z}i)$	$\widetilde{\upsilon}_i$	$X_i(x_1, x_2, x_3)$
Max $\tilde{Z}1$	(50, 23, 50)	X_1 (4, 5, 0)
Max $\tilde{Z}2$	(41, 53, 89)	X_2 (4, 5, 0)
Max $\tilde{Z}3$	(−19, 32, 13)	X_3 (4, 5, 0)
Max $\tilde{Z}4$	(−28, 36, 46)	X_4 (4, 5, 0)

$$Max\ \tilde{Z}(x) =_{\Re} \left[\frac{\{(5,2,5)x_1 + (6,3,6)x_2 + (5,3,7)x_3\}}{50,23,50}\right] \oplus \{(4,7,11)x_1 + (5,5,9)x_2 + (3,6,10)x_3\} \oslash (41,53,89)] \oplus \left[\frac{\left\{(-1,3,2)x_1 + (-3,4,1)x_2 + \left(\frac{-5}{2},9,7\right)x_3\right\}}{-19,32,13}\right] \ominus \{(-3,4,4)x_1 + (-3,4,6)x_2 + (-3,4,8)x_3\} \oslash (-28,36,46)] \quad (10)$$

$$s.t. 3x_1 - x_2 + 3x_3 \le 7$$
$$-2x_1 + 4x_2 \le 12$$
$$-4x_1 + 3x_2 + 8x_3 \le 10$$
$$x_j \ge 0, j = 1,2,3$$

This is equivalent to:

$$Max\ \tilde{Z}(x) =_{\Re} \left(\frac{211}{5584},\frac{671}{673},\frac{99}{94}\right)x_1 + \left(\frac{-263}{11392},\frac{1653}{1336},\frac{746}{627}\right)x_2 + \left(\frac{-568}{8665},\frac{312}{211},\frac{159}{113}\right)x_3$$
$$s.t. 3x_1 - x_2 + 3x_3 \le 7$$
$$-2x_1 + 4x_2 \le 12 \quad (11)$$
$$-4x_1 + 3x_2 + 8x_3 \le 10$$
$$x_j \ge 0, j = 1,2,3$$

The standard form of the above FLP problem is:

$$Max\ \tilde{Z}(x) =_{\Re} \left(\frac{211}{5584},\frac{671}{673},\frac{99}{94}\right)x_1 + \left(\frac{-263}{11392},\frac{1653}{1336},\frac{746}{627}\right)x_2 + \left(\frac{-568}{8665},\frac{312}{211},\frac{159}{113}\right)x_3 + \tilde{0}\sum_{j=1}^{3} s_j$$
$$s.t. 3x_1 - x_2 + 3x_3 + s_1 = 7$$
$$-2x_1 + 4x_2 + s_2 = 12$$
$$-4x_1 + 3x_2 + 8x_3 + s_3 = 10$$
$$x_j \ge 0, j = 1,2,3 \quad (12)$$

Now, using $\Re$ in (2), through simplex method the solution of the FLP problem (12) is as shown in Table VI.

From Table VII, we have

$$\left\{\left(\tilde{z}_j - \tilde{c}_j\right)\right\} =_{\Re} \left\{\begin{matrix}\left(\frac{-211}{5584},\frac{99}{94},\frac{671}{673}\right),\left(\frac{263}{11392},\frac{746}{627},\frac{1653}{1336}\right), \\ \left(\frac{568}{8665},\frac{159}{113},\frac{312}{211}\right),\tilde{0},\tilde{0},\tilde{0},\end{matrix}\right\}.$$
$$j = 1,\ldots,6$$

Since,

$$\{\gamma_j\} = \left\{\Re\left(\tilde{\gamma}_j\right)\right\} = \left\{-\frac{329}{6348},\frac{399}{11414},\frac{719}{8616},0,0,0\right\}, j = 1,\ldots,6$$

thus, x_1 should enter the basic solution and the leaving variable is s_1. The result is as shown in Table VII.

In Table VII, since

$$\left\{\left(\tilde{z}_j - \tilde{c}_j\right)\right\} =_{\Re} \left\{\begin{matrix}\tilde{0},\left(\frac{81}{7721},\frac{396}{257},\frac{9661}{6155}\right),\left(\frac{161}{1558},\frac{351}{146},\frac{1033}{408}\right), \\ \left(\frac{61}{4843},\frac{671}{2019},\frac{33}{94}\right),\tilde{0},\tilde{0}; j = 1,\ldots,6\end{matrix}\right\}$$

and

$$\{\gamma_j\} = \left\{\Re\left(\tilde{\gamma}_j\right)\right\} = \left\{0,\frac{106}{5995},\frac{961}{7104},\frac{511}{29579},0,0\right\} \ge 0, j = 1,\ldots,6.$$

Thus, according to the optimality feasible condition, no more variable may enter the basis, and the OS for the problem (12) is

$$\left\{\tilde{Z}; X\left(x_1,x_2,x_3\right)\right\} = \left\{\left(\frac{1477}{16752},\frac{4697}{2019},\frac{231}{94}\right); X\left(\frac{7}{3},0,0\right)\right\}.$$

TABLE VI
THE STATUS OF THE COMPROMISE SOLUTION-1

B	$\widetilde{ci}$	RHS	$\left(\frac{211}{5584},\frac{671}{673},\frac{99}{94}\right)$	$\left(-\frac{263}{11392},\frac{1653}{1336},\frac{746}{627}\right)$	$\left(-\frac{568}{8665},\frac{312}{211},\frac{159}{113}\right)$	$\tilde{0}$	$\tilde{0}$	$\tilde{0}$	Min ratio
			x_1	x_2	x_3	s_1	s_2	s_3	
s_1	$\tilde{0}$	7	3	−1	3	1	0	0	$\frac{7}{3}\leftarrow$
s_2	$\tilde{0}$	12	−2	4	0	0	1	0	-
s_3	$\tilde{0}$	10	−4	3	8	0	0	1	-
	$\tilde{z}$	$\tilde{0}$	$\left(\frac{-211}{5584},\frac{99}{94},\frac{671}{673}\right)$	$\left(\frac{263}{11392},\frac{746}{627},\frac{1653}{1336}\right)$	$\left(\frac{568}{8665},\frac{159}{113},\frac{312}{211}\right)$	$\tilde{0}$	$\tilde{0}$	$\tilde{0}$	$\Re$

TABLE VII
THE STATUS OF THE COMPROMISE SOLUTION-2

B	$\widetilde{ci}$	RHS	x_1	x_2	x_3	s_1	s_2	s_3	Min ratio
x_1	$\left(\frac{211}{5584},\frac{671}{673},\frac{99}{94}\right)$	$\frac{7}{3}$	1	$-\frac{1}{3}$	1	$\frac{1}{3}$	0	0	
s_2	$\tilde{0}$		0	$\frac{10}{3}$	2	$\frac{2}{3}$	1	0	
s_3	$\tilde{0}$	$\frac{58}{3}$	0	$\frac{5}{3}$	12	$\frac{4}{3}$	0	1	

$\tilde{z}\left(\frac{1477}{1672},\frac{4697}{2019},\frac{231}{94}\right)\ \tilde{0}\left(\frac{81}{7721},\frac{396}{257},\frac{9661}{6155}\right)\left(\frac{161}{1558},\frac{351}{146},\frac{1033}{408}\right)\left(\frac{61}{4843},\frac{671}{2019},\frac{33}{94}\right)\tilde{0}\ \tilde{0}\ \Re$

Moreover, this is the compromise solution for the original problem in (8).

VIII. Conclusion

We considered MFLP problems with BFS. We proposed a new technique to transform these multiple optimization problems into a single FLP problem. The compromise solution has been found for the resulted problem by using linear ranking function through simplex method. We believe the technique is practicable in real life.

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Evolved Sustainable Building Engineering in Vernacular Architecture of Kurdistan

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***Abstract*–Vernacular architecture in Kurdistan is a widely understudied subject. Whilst rapid development is taking place across the Kurdistan region of Iraq, the lack of a clear knowledge of local building traditions has led to the loss of locality and engineering adaptability of newly developed buildings. Advances in mass development in the Kurdistan region need to have clear signs of Kurdish cultural heritage alongside lasting and sustainable solutions. The study of mountain villages of rural Kurdistan will provide valuable information about sustainable building practices as well as cultural values in regional settlements. This, in turn, will be useful in finding more adoptable green choices in the region and identifying the characteristics of the evolved building engineering of these indigenous settlements. This paper will first describe the characteristics of the evolved engineering and sustainable adoptions of Kurdish historical building traditions through selected site visits to Kurdish vernacular settlements and then analyses the building customs of rural communities of Kurdistan for possible adoption in contemporary developments.**

***Index Terms*–Evolved engineering, Green solutions, Kurdistan, Sustainable building, Vernacular architecture.**

I. Introduction

From time to time, many people from the towns and cities in the Kurdistan region leave their busy environment to visit the countryside. Beautiful villages, rural landscapes, and mountains within close distance of cities are the destination for families and individuals seeking a few hours' break from stressful urban life.

People driving through different parts of the Kurdistan region can easily notice that Kurdish traditional houses are not the same. Often the buildings that make up rural landscapes appear noticeably different in their choice of building materials and also in their style, size, and form. Matthew (2010) explains that people gradually realize that these variations are not just random patterns, but each house varies from the next in a logical and pleasantly appealing way. "These patterns must surely mean something; they must surely tell us something about the history of the household, community, and region" (Matthew, 2010).

In the Kurdistan region, such patterns within rural settlements can reveal the clear variation in building styles and forms of houses which are imposed by the availability of local material, geographical location compared to a major regional center, or ease of access to major communication routes.

Nevertheless, houses are about people. Architecture is a human creation. It is about people acting on their surroundings in building their shelters. The small houses of the countryside can tell us about the lives of the ordinary people who built them and who lived in them. The variation in buildings in different areas reflects the variations in "culture, rituals, ways of life, and social organization, climates and landscapes, and materials and technology available, while the similarities are evidence not only of areas where some or all of these factors have coincided but also of some basic constancies in man's needs and desires" (Rapoport, 1969). These remarkable evolved buildings are providing know-how for creating modern buildings with local cultural footprint.

Oliver (1997) identifies vernacular architecture as the common dwellings and other native buildings of the people. These creations are directly connected to environmental factors, available resources, and traditional technologies. He emphasizes that "all forms of vernacular architecture are built to meet specific needs, accommodating the values, economies, and ways of life of the cultures that produce them" (Oliver, 1997).

Vernacular architecture is a building process that evolved in response to the basic necessities of life of individuals or communities and reflects many factors such as the environmental, cultural, economic, and technical evolution of the people creating it. Vernacular architecture in Kurdistan has not been subject to wide study and through this lack of knowledge is losing significance amid the rapid developments taking place in traditional communities. The purpose of this study is to shed light on the characteristics of Kurdish vernacular architecture through selected field research, interviews with local people and an analysis of building traditions in rural Kurdistan and to illustrate preserved examples in surrounding communities. The study of vernacular architecture in Kurdistan can provide valuable

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data about sustainable local building traditions, which can be useful in identifying sustainable green choices for new developments in the region. The data can provide grounds for further research and understanding as well as transferring knowledge to local and global educational institutions. The wider understandings can help the public to preserve their building traditions and heritage using new design concepts influenced by the characteristics of local culture.

This study began in early 2013 as a course module in the Architectural Engineering Programme (DARE) at Koya University. A total of 19 students from 5th year DARE were exposed to the concept of vernacular architecture for the first time and given the opportunity to visit, examine and collect data from two sites at Tewélle and Bíyare. The study continued with visits to sites with various climatic conditions such as Béxall, Deke, Kifrí, Amédí, and Rewandiz (Table I). This paper provides an overview and analysis of selected findings.

II. Importance Of This Study

The Kurdistan region of Iraq has been enjoying a semi-independent status in recent years. It has been described as a source of peace and development in the Middle East. In reality, its long history of war and violence has left indelible marks and scars. At the same time, however, it has created a unique situation marked by a free market and developing opportunity (Recchia, 2012).

It is important to know that Kurdistan has been home to many surviving ancient indigenous religions such as Yezidism, Yarsanism, and Alevism as well as Islam, Judaism, and Christianity. Inhabitants with these beliefs have been building structures to satisfy their basic needs using their accumulated skills over millennia. Their structures have been shaped and influenced by their particular beliefs and culture, as well as environmental factors. This study sheds light on the cultural factors that explain how building under these circumstances has allowed for the creation of dwellings that are sustainable and culturally accepted in surrounding environments.

The Kurds and their lifestyle have been noted in the narratives of Western travelers, who have mentioned villages that were built on rocky hills where they were surrounded by strong stone walls and built with the most substantial materials (Shiel, 1836). The rough mountainous environment clearly imposed characteristic local conditions on sustainable building traditions which have ensured their survival. Mountain villages such as Tewélle and Bíyare and hill towns such as Amidé and Rewandiz, as well as lower plains towns such as Kifrí are good examples of such survival communities which are still inhabited. Studying the dwellings' building conditions reveals that the materials used for the dwellings in the region differ depending on average annual temperature climate variations which range from +50°C to −10°C. Mudbrick, rubble stone, and timber were variously used. "The modern Kurdish domestic vernacular settlements are not any different from those that were unearthed from archaeological sites, as mudbricks and domed roofings are employed in the drier zones, while rubble stone walls and wood beam roofs, serve the wetter, and higher zones" (Izady, 1992).

TABLE I
Geographic Position of And Climatic Variations Sites Visited for This Study With Extrapolation (Pauw, et al., 2015)

Site name	Latitude	Longitude	Sea level (m)	±°C temperature
Amédí	37.0917271	43.4876920	+1190	−10 to +38
Béxall	35.200733	46.14820250	+1432	−12 to +35
Bíyare	35.2250909	46.11596450	+1076	−12 to +35
Deke	34.4183534	45.29098922	+150	0 to + 50
Kifrí	34.6886731	44.9580161	+230	−2 to + 50
Rewandiz	36.6085381	44.5238693	+752	−10 to + 40
Tewélle	35.2013534	46.18404750	+1477	−12 to + 35

*Some final digits may be missing in the latitude and longitude columns

Lafforgue (2010) clearly captures in Fig. 1 an image of settlements which showcases the environment, materials, and cultural significance of vernacular architecture in the Kurdistan region in general. Studying the building conditions in these settlements shows the richness in cultural and social harmonies that has evolved among the inhabitants. In fact, Oliver (1987) explains that vernacular traditions "are not anachronistic survival(s) of a vanishing world, but are evidently important to the future provision of culturally appropriate and sustainable architecture" (Oliver, 1987). Although the dwellings observed in this study were mostly small houses with a couple of rooms with shared roofs which were built using traditional evolved engineering solutions such as stone arches and flat roofing, they all share a common link of being built by people following local customs using local materials. The study highlights these good practices from local building traditions to exemplify possible future wise choices for developments with a focus on vernacular evolved engineering concepts. Studying such vernacular communities can ensure the survival of a valuable heritage which can contribute to the transformation of our modern communities through greater adaptability.

III. Focus Of The Study

Vernacular architecture is created through simplicity of basic needs influenced by various factors. Arboleda (2006) states that vernacular architecture is a field in architectural studies that deals with the dwellings made by often self-taught builders without the knowledge of architecture as a profession. The author interviewed Mr. Abdulla at a building site in the town of Tewélle, pictured in Fig. 2, who said he learned to become a mason (locally called a *tewentash*) by working with his father from the age of 10. He said he makes a connection with every single stone he prepares and often revisits the buildings that have been built with his stones (Fig. 2).

There are many types of practical architectural applications, from primitive or the shelters in distant communities to urban adaptations of building types that are imported depending on the level of interaction and communication between neighboring communities. Due to that factor vernacular

Fig. 1. A view of the well-preserved Kurdish village of Palangan, a UNESCO World Heritage listed site which attracts many tourists every year. (Source: Lafforgue, 2010)

Fig. 2. Mason working on building site in town of Tewélle. (Author, 2013)

architecture is a very open, comprehensive concept (Arboleda, 2006). The average member of such communities "builds his own house, he understands his needs and requirements perfectly; any problems that arise will affect him personally and be dealt with" (Rapoport, 1969). This study explores and focuses on whether the vernacular architecture in Kurdistan's distant communities presents any characteristics in its building traditions with evolved technologies that can be useful to new developments which have local impacts.

Vernacular architecture in Kurdistan as a topic has not been the focus of wider study before. The only attempt to bring together researchers in the region took place at an International Conference on "Zagros Traditional Settlements" (ZTS, 2008), yet the proceedings of this conference are not publicly available. There have also been other studies on rather traditional trends in building styles of urban environments such as Khayat and Khaznadar (2010).

It is widely believed that culture is dynamic and evolves while maintaining core elements that distinguish one tradition from another. Hardie (1985) states that architecture, viewed as a physical expression of culture, similarly reflects cultural continuities and changes (Hardie, 1985). However, Rapoport (1969) indicates that not all elements go through transformation but "certain forms are taken for granted and strongly resist change since societies like these tend to be very tradition oriented" (Rapoport, 1969).

Sites visited by the researchers in this study in various parts of the Kurdistan region also represented variations in local culture and lifestyle, from the warm, lower altitude areas to the colder, higher altitude areas, with a sense of physical expression of the various locations.

This study primarily focuses on the Kurdistan region in Iraq and discusses comparative characteristic elements of wider Kurdistan where needed and focuses on three main areas namely:

- A comparative analytical view of vernacular architecture in Kurdistan
- Eco-friendly concepts of vernacular architecture in Kurdistan
- Evolved engineering concepts in the vernacular architecture of Kurdistan.

The methodology of the study was directed toward discovering concepts and definitions related to vernacular architecture and settlements. The research required information to be collected through site visits, photos, and interviews and presented in a descriptive, analytic way. This study introduces lessons from evolved vernacular settlements of Kurdistan valuable for this education and the modern construction industry. There will be other matters that will be identified and outlined for further studies with suggestions for wider research on various aspects of vernacular architecture in Kurdistan.

IV. Vernacular Architecture in Kurdistan

The Kurds are the native inhabitants of their land; there are no "beginnings" for Kurdish history and people, writes Izady (1992). "Kurds and their history are the results of thousands of years of continuous internal evolution and assimilation of new peoples and ideas introduced sporadically into their land. Genetically, Kurds are the descendants of all those who ever came to settle in Kurdistan, and not any one of them. Archaeological finds continue to document some of the mankind's earliest steps toward development of villages and agriculture. Development of domestic technologies such as weaving, fired pottery making and glazing, sun-dried mudbricks and stone cutting for building, metallurgy, and urbanization took place in Kurdistan, dating back between 12,000 and 8000 years ago" (Izady, 1992).

Contemporary Kurdistan as a geographical region has been divided mainly between Turkey, Iran, Iraq, and Syria since the early 1900s (Fig. 3). These sectors of Kurdistan have been in conflict with central governments over their cultural, historical, political, and human rights since the creation of modern local state boundaries in the Middle East in the 1920s. Thus, Kurdistan and its people have not been the focus of wide academic studies, in particular, building environments and traditions.

The climate in the region ranges from a hot desert facing lowland Mesopotamia with an altitude of just 150 m above

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Fig. 3. Kurdistan divided between four countries. (Source: Izady, 2015)


Fig. 4. The picturesque village of Amédí, Kurdistan. (Source: Nelson, 2009)

sea level, with temperatures that can rise as high as +50°C to a cold mountain environment inside the region with altitudes of above 1500 m above sea level with temperatures as cold as −10°C. There are signs of climate adaptation in every corner of Kurdistan which indicate the use of local materials to create a sustainable comfort zone for living. This is reflected in vernacular building style using building materials such as typical natural limestone, fieldstone, or fashioned masonry in mountainous areas of the region such as Rewandiz, Amédí, and dolomite rocks in rougher areas such as Tewélle (Jassim and Goff, 2006). The city of Amédí (Fig. 4), in the Northern part of the Kurdistan region, is a perfect example of a community adopting a natural fortress for security, local material for availability, shared cultural values for building a close community and strong thick stone walls for climate adaptability. Houses are built with local materials, creating a cultural representation in perfect harmony with their surrounding environment.

Aristova (1996) stated that most Kurds live in small villages in remote mountain regions. A typical Kurdish house is made of mudbrick with a wooden roof (Aristova and Testen, 1996). Sun-dried mudbricks, usually quadratic in form, have been common building materials in the warmer, drier lowlands of Kurdistan. The traces of large mudbrick reinforced with animal hair and hay date back millennia. Mudbricks first appeared in the 8th-7th millennia BC in the walls of the Neolithic settlement at "Ganj Dareh" in the South Kurdistan (Smith, 1974), where they were set in mud mortar. This is almost four millennia older than the Egyptian pyramids. Mudbrick walls and facades are the most common sight across lower Kurdistan as well as in the most studied archaeological sites such as Chermo 7th millennium BC, and Béstan Súr 11th millennium BC. These are material and climatic characteristics that are still preserved and have become important factors for regional sustainable adaptation.

Ozel, et al. (2014) argue that the main feature of vernacular communities is the "collective living" style. Individuals collaborate to deal with the challenges of everyday life and to resolve common problems such as the need for shelter and the production of food (Ozel, et al., 2014). However, it is quite interesting to note that Kurdistan's vernacular communities provide efficient solutions to the climatic and topographic constraints of this region and resemble harmonious social and cultural adaptability to their environment with their collective building skills. The environmental sustainability achieved in the mountain villages of Kurdistan includes the settlement patterns, building forms, and topographic locations that are consistent with the region's microclimatic characteristics and collective skills.

The type and shape of buildings and their orientation, the integration with surrounding nature, and the arrangement of the external and internal space have been carefully evolved to ensure the best possible usability with comfort. The impact of climate on building traditions reveals feasible evolved measures that have been adopted such as natural ventilation systems and passive solar heating. These features are critical given the temperature variations between −10°C and 50°C in mountainous parts of the region with cold winters and

occasionally heavy snows that melt in early spring, and the region's lowlands with typically mild to cool winters with dry, hot, cloudless summers. Hosseini and Shangapour (2010) believe that the accurate use of local natural materials, the design of openings and their shading, natural cooling, passive solar heating and the all-round arrangement against cold winds are important supporting elements of a well-achieved sustainable conditions in such varying climatic conditions (Hosseini and Shangapour, 2010).

In Kurdish vernacular architecture, colors, patterns and sunlight play a significant role. The required solar energy is obtained through factors such as materials, window placement, spatial arrangement, and suitable terrain. Small square sky blue wooden windows are very common across the Kurdistan region. The shape and the color of the windows follow the same pattern across the village.

Villagers build houses on the southern side of the mountain, which gets the most possible sunlight year round, in particular, morning sunlight. The orientation of the buildings north-south secures maximum penetration of sunshine on cold winter days. Life in the village for shepherds and farmers starts with the first glimpse of early morning light that wakes up the village. The flat rooftops facing the rising sun provide an important open space and a vantage point for interaction and communication in the village, which has great cultural value. Fig. 5 illustrates a good example of a focal point for social interaction, where two Kurdish women are catching the morning sun on a flat rooftop of the UNESCO Heritage listed Kurdish Village of Palangan with its preserved and protected structures not far from the town of Tewélle, sharing many aspects of Kurdish native lifestyles (Fig. 5).

Morning sunlight and the circulation of air have always been recognized as important features of a healthy building to live in (Burgess and Wetherell, 2005). Identifying these characteristics in the vernacular architecture of Kurdistan shows the evolved adaptation of healthy building in relation to facing morning sunlight and fresh air within the buildings.

V. Climate, Materials And Evolved Techniques

It is evident that shelter is a prime necessity to mankind. It has been the dominant factor in the continuous struggle for survival. Consequently in the endeavor to shelter against harsh weather and climate mankind has evolved many types of dwellings (Rapoport, 1969). The type of dwellings varies depending on the available local materials and evolved techniques to respond to extreme regional climate variations.

For this observation, the study looks closely at data collected from the city of Tewélle in the mountainous area of the Kurdistan region for analytical review. This city is wisely situated in a narrow valley between high mountains enclosed on three sides to protect the city from strong winds at an altitude of 1450 m above sea level (Fig. 6).

The high rocky, mountains function as a natural fortress. The inhabitants work mostly in general farming, vine

Fig. 5. Kurdish women catching the morning sun on a flat rooftop in the village of Palangan in the neighborhood of Tewélle. (Source: Powell, 2008)

Fig. 6. The town of Tewélle situated hidden deep in an enclosed triangular valley at +1477 above sea level. (Source: Author, 2014)

farming, honey bee farming, handmade traditional shoes (*Killash*), scarves, and home tools as well as different dried fruits and food conserves. As it is located on the international border between Iraq and Iran, some inhabitants are engaged in exporting and importing locally produced goods. In this area, people have built their houses on the face of this high mountain for centuries using locally available materials such as stones and woods (Fig. 7).

When one observes building practices in Kurdistan, the mountain buildings likely resemble any house type in the Middle East, but a unique feature of Kurdish vernacular architecture is the practice of building stone walls without mortar. The stones are collected and sorted by excavating and preparing the same building site. This sort of dry, irregular stone walls or dry stacking is called *Wushke Kellek* (drywall) by locals. The walls are freestanding structures that use irregularly shaped stones carefully selected and positioned closely together without slipping. They are reinforced by long horizontally positioned wooden/stone

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Fig. 7. Owner of an abandoned house explains how he built his stone house and now has a concrete house down in the valley in the town of Tewélle. (Source: Author, 2014)

Fig. 9. View from the rooftop of the visited house over the valley, site visit to town of Tewélle. (Author, 2014)

Fig. 8. Positioning Dímek in the stone wall for vertical load distribution as well as withstanding earthquakes. Site visit to the town of Tewélle. (Author, 2014)

Fig. 10. Alley road to the visited house on the site visit to town of Tewélle. (Author, 2014)

planks known as *Dímek* or vertically positioned planks known as *Mirolle* in local parlance to distribute dead loads in the wall structure, withstand earthquake movement and absorb the moisture in the wall as exemplified in Fig. 8. Such solutions applied by vernacular builders indicate the evolution of trial and error to perfect workability and structural safety of the dwellings.

Two-storey houses are the most common. The entrances are generally on the ground floor. The ground floor is mostly used for common areas such as livestock, storage spaces and in larger households for a living room, and kitchen. The living areas are commonly on the upper floor. Rooms are divided into living room, kitchen, and bedroom functions.

For the purpose of this study a house was visited which was still occupied. This remarkable native building stands on a spectacular site on the upper edge of the town on the face of a mountain with beautiful views over the valley (Fig. 9).

The steep uphill alley which leads to the house is artistically decorated by irregular dry uncoursed stone walls (Wushke kellek) on both sides. The local natural stone walls perfectly engineered harmonize with the beauty of the surrounding natural environment (Fig. 10). The wall structures along these steep alley roads are typically wider at the base and thinner as height increases when used as retaining walls. The weight of the stone leans inward to support the structure, and the stones interlock to become stronger. These dry retaining walls allow water to drain through them without causing damage to the stones. They do not require any special tools, only the skill of the craftsman in choosing and placing the stones carefully.

The occupant mother of four children stated that they took over the house half built when she got married. They finished the house by their own bare hands. Since it was so high up, they got a good deal for it. She described the house as she knew every stone used to build it, two rooms for sleeping, living and resting area, and most activities at home are on the rooftops of abandoned lower section, where livestock used to be kept he stated. The lower sections of these houses used

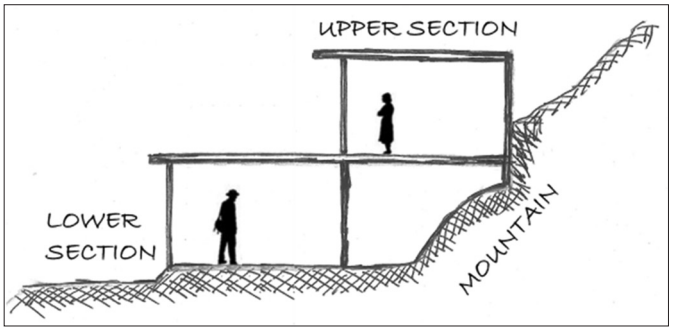

Fig. 11. Sketch showing the positions of the lower and upper sections of the visited house in the town of Tewélle. (Author, 2014)

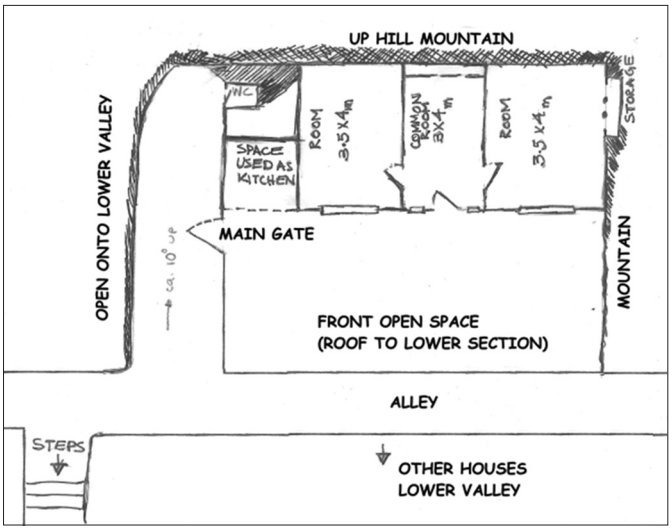

Fig. 12. Sketch showing the plan of the main living area in the upper section of the visited house in the town of Tewélle. (Author, 2014)

to be the main means of keeping the upper section warm in winter (Figs. 11 and 12).

In this house all the walls are constructed with stones and wood is used in making floors and flat roofs. All observed building types in this town lacked structural frames, but all walls in any direction were load bearing walls. The outer walls are erected with a thickness of c. 500 mm with rather small window openings to preserve the heat. The structure of the roof extension that provides cover against sunlight and rain over the outdoor living area and the surrounding walls are built with joists (*tírek*) positioned every 300 mm and beam (*kolleke*) and a post (*hellgir* or *hemall*) (Fig. 13).

Many evolved structural methods equip the building to resist the violent changes in the weather changes as well as providing comfortable living space inside. Such comforts have been achieved by considering all variations in climatic factors and represent an optimum solution. In the visited house during the warm seasons, the occupants spend most of their daytime under the extended roof area outside and sleeping on the flat roof of the lower section area at night. During the cold seasons, they keep the house warm with a single iron chimney and rely on the heat produced by livestock in the lower section of the house. In the old day's people used to build houses with much lower ceiling heights

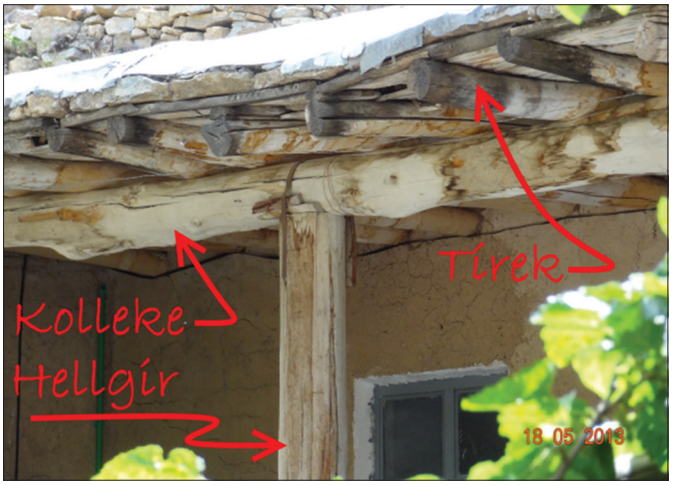

Fig. 13. View of the extended flat roof structure at the visited house in the town of Tewélle. (Author, 2014)

Fig. 14. Height of the ceiling compared with a standing person 1.73 m tall in an abandoned old house in the town of Tewélle. (Author, 2014)

to keep the house warm in the cold nights, says Mr. Faruq, a traditional builder in the town. Nevertheless, they are still using straw clay plaster to coat the inner walls and decorate them with white mud (*gillesipí*), he added (Fig. 14).

The responses to the challenge of climatic variation are clearly different in the lower part of the Kurdistan region. Fig. 15 illustrates an example of such variation of evolved engineering concepts to achieve comfortable indoor air quality by allowing cross ventilation of natural air circulation for maximum output. This evolved solution is built on thermal air movement by letting the cooler air freshen, the higher density air through a filtered opening in the lower shaded section of the house and pushing the warmer lower density out from the upper opening of the opposite wall (Fig. 15). The temperature in the region's lower plain can go up to +50°C in hot seasons.

It is evident that the rugged cold mountain climate has led to the adoption of very close communities with a greater sense of belonging and security. Fig. 16 explains a common housing layout on where cubic buildings on the slope of a

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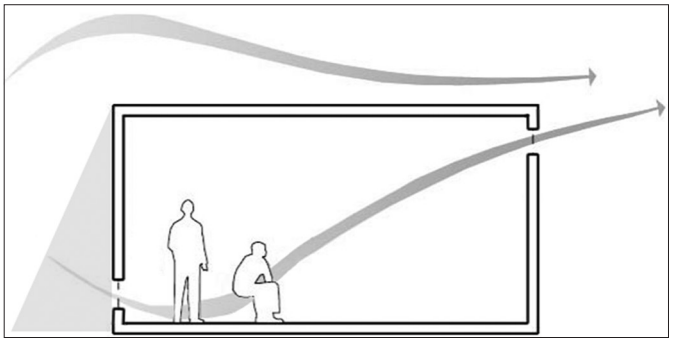

Fig. 15. Kurdistan vernacular cross ventilation solution in Germíyan province. Impression from site visit village of Deke in 2013.

Fig. 16. Space for ritual and social gathering. (Source: Zabihi and Arshi, 1990)

mountain have been organized to allow for social interaction and gathering spaces as well as preserving thermal energy. Here an optimum adoptable solution of durability has been achieved through trial and error and has been passed down the generations. Rooftops are built to withstand the heavy dynamic loads of an assembled crowd for occasional ritual ceremonies as well as public space. The structure of these roofs consists mainly of timbers that are arranged to distribute heavy loads to load bearing stone walls.

The timber framework of roofs in these traditional houses represented roof-frame structures with strong durability (Fig. 17). Such a roof structure is made of large ceiling joists (*tírek*) on which roofing battens (*darerra*) and roofing planks are laid as internal lathing for roof cladding. On top, the timber is coated with daub mixed with chopped wheat straw or something similar. Several thin layers of mud and daub (*topelle qorr*) are added and compacted with a stoneroller (*bangilan* or *sírekollé*) to create a waterproof, durable state. There is also a seasonal pattern to the occupation of space by which people sleep on the front veranda or on the flat roof during summertime. Often an open veranda (*eywan*) is created in front of the house using heavy beams (*kolleke*) supported by columns (*sitún or hellgir*) to extend the space created on the roof and shade the outdoor space during the day.

Fig. 17. Roof structure of typical house at the house visited in the town of Tewélle. (Author, 2013)

Fig. 18. Cube-shaped houses of mountain village on the slope to catch the morning sun and preserve lower land for agriculture, Hawraman Text, Kurdistan. (Source: Tuli, 2010)

VI. Impression Of Vernacular Architecture

Self-sustained societies in various environmental conditions have developed a unique vernacular architecture. The architecture of these communities has been formed for purely basic life needs and protection, to accommodate basic necessities for the inhabitants (Sangiorgi, 2008). The blending of nature and dwellings has developed unique architectural characteristics distinctive to Kurdistan with characteristic techniques. The way buildings are shaped mainly depends on the limits imposed by the local environment, thus providing valuable data for new developments.

In spite of its immense value, the rural vernacular heritage in the Kurdistan region is threatened on several fronts such as rural depopulation, which is in part a result of many social and political changes. The rural population may leave buildings unused and perhaps abandoned. Furthermore, the majority of villages once destroyed by the atrocities of Saddam's regime (1979-2003) have not been repopulated again. However, traditionally rural settlements represent the

Fig. 19. New town houses inspired by vernacular settlement, local materials, small windows, and cubic forms in the town of Tewélle. (Author, 2014)

Fig. 20. A modern design inspired by vernacular concepts, natural local stone and cubic design with small windows in the town of Bellxe. (Author, 2014)

Fig. 21. Entrance to the old bazaar before refurbishment. Site visit to the city of Suleimani. (Author, 2013)

Fig. 22. Refurbished section of the entrance to the old bazaar. Site visit to city of Suleimani. (Author, 2015)

best mixture of people's ability to modify the environment to their own advantage with the least impact (Battaini-Dragoni, 2008). The harmonious communities in vernacular settlements such the one illustrated in Fig. 18 abandon their lifestyle and migrate to cities in search of a better life and disconnect from centuries of experiences living in traditional buildings in vernacular communities.

The shift of population from rural to urban life may not always make a negative impact on urban building traditions. There are good though rare examples of buildings inspired by vernacular architecture in newly developed townhouses in the town of Tewélle (Fig. 19), which offer far better adaptability to for their native environment than some modern building styles.

Some adventurous new homeowners are taking up the challenge of creating new dwellings that are purely inspired by their local vernacular architecture. The creative new buildings are transforming the landscape and displaying examples of how vernacular architecture can preserve indigenous building traditions and promote sustainable ideas with local characteristics (Fig. 20). This rather modern villa in the town of Bellxe displays how dry stone walls, cubic forms, and local material can present a more pleasing appearance within their environment.

Learning lessons from vernacular architecture and design can transform our communities and provide better cultural values (TCPA, 2007). The vernacular architecture of regional rural landscapes may bring answers to the challenges imposed by climate change in the region. Vernacular architecture is designed to suit centuries of local climatic variations and is a reflection of the customs and surrounding natural landscape of a community such as in the adoption of local values in the ambitious projects presented in Figs. 21 and 22. The long forgotten, locally inspired buildings in our city, can be restored and claim their rightful place in our urban environment and impress with better locally, adapted engineering and architectural solutions.

An awareness of local issues such as material, climate, space, economy, expansion, and cultural values related to building development and the technological capacity to solve these problems is needed. The cities of the future are going to be the ones which are flexible and scalable. We need nature in the city with access to open space for interaction. "It is not number, crowds, and city size that matter but

sense that city space is inviting and popular that creates a meaningful place" (Gehl, 2013). Creating popular culture surrounding these expectations needs local understanding to introduce solutions with the higher adaptability that are local and environmentally sustainable with green engineering and materials.

VII. Recommendations

The recent rush in regional developments has deeply affected building materials and techniques as well as the definition of space. Cellular concrete blocks have replaced sun-dried mudbricks or natural stones (Rostam, et al., 2016); galvanized iron, plastic sheets, or precast concrete roofing have replaced timber framed mud straw as a roof covering. Builders are no longer the traditional specialists, but commercial builders. The spatial pattern of these new houses does not resemble the traditional local design. Spaces are more specialized; the seasonal shifts within the domestic space are now compromised, and a sense of privacy is more emphasized within the same community.

This study makes recommendations to create a platform for general debate and further studies as well as the possibility of establishing a permanent academic research group to shed light on valuable human heritage in this region. The study has as far as possible identified the lessons for sustainable solutions using local materials and the significance of preserving the local indigenous building traditions which have evolved to a harmonious engineering perfection with its surrounding environment through millennia. Engaging public opinion with this heritage will allow the public and the industry to have an impact on preserving the culture and the identity of building traditions in Kurdistan. The construction industry can build with these local values and evolved engineering knowledge with greater sustainable impacts.

VIII. Conclusions

The vernacular settlements of Kurdistan can be identified as centuries of adaptation to the environment, making use of natural local materials as well as evolving building techniques. Through this study, various characteristics of vernacular architecture were explored and highlighted, with recommendations on how they can contribute to sustainable solutions with greater local authenticity. The key features concerning sustainability in vernacular architecture were identified by analyzing some data collected from vernacular settlements in various topographical regions with a variety of climatic, site, and material factors such as in the towns of Tewélle and Bellxe, and the village of Deke. This building rush and the impact of lack of understanding of local sustainable building traditions has been analyzed. The negative impact on rural and urban development has been outlined, and some rare examples have been presented to show the hidden possibilities that regional vernacular heritage can offer through their local designs.

It is evident that vernacular settlements are clear proof of human activity in certain places with historical building tradition footprints. If they are left to perish, part of our history will be lost forever. This paper has provided an understanding of the landscape, the environment, the land and the people as cornerstones for the creation of our indigenous communities. Our endeavor is to preserve our building traditions not only as a part of our history but also as a valuable resource for the future development of our housing and urban planning. Nevertheless, in a short span of time, the vernacular architecture of the region, an important aspect of Kurdistan's popular culture and heritage, is on a path to completely vanishing.

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Kurdish Dialects and Neighbor Languages Automatic Recognition

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***Abstract*–Dialect recognition is one of the hottest topics in the speech analysis area. In this study, a system for dialect and language recognition is developed using phonetic and a style-based features. The study suggests a new set of feature using one-dimensional local binary pattern (LBP). The results show that the proposed LBP set of the feature is useful to improve dialect and language recognition accuracy. The acquired data involved in this study are three Kurdish dialects (Sorani, Badini, and Hawrami) with three neighbor languages (Arabic, Persian, and Turkish). The study proposed a new method to interpret the closeness of the Kurdish dialects and their neighbor languages using confusion matrix and a non-metric multi-dimensional visualization technique. The result shows that the Kurdish dialects can be clustered and linearly separated from the neighbor languages.**

***Index Terms*—Dialect recognition, Language processing, Speech analysis, Machine learning, Local binary pattern**.

1. Introduction

Dialect is the language variation of a population established based on various real-life conditions (Chen, et al., 2010). Recently, dialect recognition (DR) has become a hot topic for its wide applications in speech recognition and forensic. Adapted speech recognition system needs different tools such as the recognition of the dialect or the accent to normalize the speech samples for speech recognition system. For example, Hirayama, et al. (2015) develop an automatic speech recognition system that accepts a mixture of various kinds of dialects.

There are several challenges in DR research area, such as the collection of speech data, which needs to model the diversity of the studied dialects and/or languages (Diakoloukas, et al., 1997). The conclusions made by the researches on DR are mostly restricted to the available collected data. Consequently, generalizing the developed algorithms starting with the set of the used feature or the classification methods is generally non-convincing. For this reason, some studies focus on using collected data under specific condition which "preserve" the real-life characteristic of the data. A study made by Huang and Hansen (2007) addresses novel advances in unsupervised spontaneous DR in English and Spanish. The problem considers the case where no transcripts are available for training and test data, and speakers are talking spontaneously. In this study, we adopt the use of spontaneous speech signals recorded from show and debate TV programs.

In the literature, some of the studies focus on investigating the nature of dialect speech signals. For example, in Bahari, et al. (2014) a non-negative factor analysis approach is developed for Gaussian mixture model (GMM) weight decomposition and adaptation. Their study show that GMM weights carry less, yet complimentary, information to GMM means for language and DR. In addition, in Patil and Basu, 2009, a new method of machine learning, called modified polynomial networks is proposed for the DR problem in an Indian language. The proposed algorithm for machine learning is interpreted as designing a neural network by viewing it as a curve fitting (approximation) problem in a high-dimensional space with the help of radial-basis functions.

The research of language and DR is widely using template based and/or phonetic based techniques. The template-based DR adopts the use of global parameters of the speech signal regardless the specific characteristics of the available phonemes related to each dialect. This kind of studies has been frequently used as in Choueiter, et al. (2008) which find that a purely acoustic approach based on a combination of heteroscedastic linear discriminant analysis and maximum mutual information training is very effective. However, phonetic-based DR is also adopted and compared with acoustic and token-based DR and also found to be effective as in Diakoloukas, et al. (1997).

Another approach that adopted for DR is phonetic based recognition of dialect. This approach adopts the use of local feature that reflects the presence of various phonemes in each language or dialect. For example, Chen, et al. propose supervised and unsupervised learning algorithms to extract

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dialect discriminating phonetic rules and use these rules to adapt biphones to identify dialects. They discovered that dialect discriminating biphones compatible with the linguistic literature while outperforming a baseline monophone system by 7.5% (Chen, et al., 2010). While in Chen, et al. (2011), the authors propose an informative DR system that learns phonetic transformation rules and uses them to identify dialects. A hidden Markov model is used to align reference phones with dialect-specific pronunciations to characterize when and how often substitutions, insertions, and deletions occur.

This study adopts a template-based DR from speech signal using global phonetic based features. It also introduces a new style-based feature (one-dimensional local binary pattern [1DLBP]), which is not used in DR so far. The study used data recorded from three Kurdish dialects (Sorani, Badini, and Hawrami). It also involves Arabic, Persian and Turkish as three neighbor languages to study how independent the Kurdish dialects from those languages, which supposed to have an influence on each other based on cultural and geographical interactions. The study proposes a method to visualize the recognizer confusion between different dialects and languages.

The rest of this paper is structured based on the following sections: In section, two feature extraction procedures are presented, followed by the description of the data used in section three, next to that the methodology is shown in section four, and finally discussion of the result and the conclusion are presented in sections five and six.

II. Feature Extraction

As any pattern recognition process, the DR includes some major steps starting with feature extraction. In DR, mel frequency cypstrum coefficients (MFCC) and linear prediction coefficients (LPC) based features are well known for its capability to model the phonetic characteristic of the speech signal (Choueiter, et al., 2008; Patil and Basu, 2009). In this study, global features (average and standard deviation) of 12 MFCC and 12 LPC on windows of length 30 and 15 ms overlap are computed. However, besides the MFCC and LPC, the study introduces a 1DLBP feature, which model the style of the speech, and investigates its benefit for DR. 1DLBP is adopted in many other applications such as Guo, et al. (2010) and Abdul, et al. (2016).

The 1DLBP operator labels every single value of the vibration signal by considering its neighborhoods and using the value of the center position as a threshold for the neighborhoods. If the neighbor value is less than the center value, the value of the neighbor will turn to 0; otherwise, it turns to 1. A LBP code for a neighborhood is then produced. The decimal value of the LBP binary code presents the local structural knowledge around the fixed value.

The histogram of the 1DLBP signal displays how often these various patterns appear in a given signal. The distribution of the patterns denotes the whole structure of the signal. The 1DLBP operation of a sample value can be defined as:

$$LBP_P\left(x\left[i\right]\right)=\sum_{r=0}^{\frac{P}{2}-1}\left\{\begin{matrix} f\left[x\left[i+r-p/2\right]-x[i]\right]2^r+ \\ s\left[x\left[i+r+1\right]-x\left[i\right]2^{r+\frac{p}{2}}\right] \end{matrix}\right\} \quad (1)$$

Where f is the sign function:

$$f\left(x\right)=\begin{cases}0, x<0\\ 1, x\geq 0\end{cases} \quad (2)$$

And x[i] is the signal and p is the number of considered neighbors. The Sign function f[x] transforms the differences to a P-bit binary code.

In this paper, only eight neighbors are considered (four to the left of the center and four to the right). Equation (1) illustrates how the 1DLBP is evaluated. Hence, the value range of the new signal is between 0 and 255. The obtained signal is discriminated into two parts, uniform and non-uniform number. The uniform number comprises the numbers with fewer than or equal to two transition bits from 1 to 0 or 0 to 1 in their circular bit patterns. The non-uniform numbers have more than two transition bits. For instance, the patterns 11111111 (0 transitions) and 10001111 (2 transitions) are uniform, while the patterns 10101 (4 transitions) and 01010111 (6 transitions) are non-uniform. There are 58 uniform numbers in the range 0–255 and the rest are non-uniform numbers. The histogram is computed such that an independent bin represents each uniform number, while all the non-uniform numbers are represented in one bin. Therefore, the set of features consists of 59 bins, 58 of them for each uniform number and one bin for all non-uniform numbers. These bins are utilized as features of the dialect speech signals. The number of bins in the histogram depends on how many neighbors are considered. Fig. 1 demonstrates a 1DLBP operator for number of neighbors (p=6), with the center sample as given. After processing 1DLBP, the 6-neighbor samples in the example above produce the 100101 codes. The code is then converted to a decimal system number (=37) and substituted in the same index of the center sample.

A. Data Discription

Data acquisition is an important task in any classification process. The data collected in this paper consists of three Kurdish dialects (Sorani, Badini, and Hawrami), and three different languages (Arabic, Persian, and Turkish) recorded from TV broadcasts. For each dialect and individual

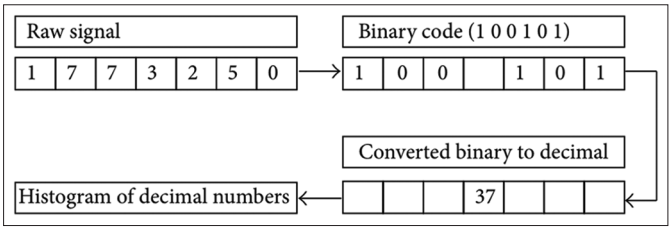

Fig. 1. One-dimensional local binary pattern, number of neighbors (p=6).

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language, 15 different speakers are involved; each speaker has three different 2 s duration recordings. Consequently, 45 samples are recorded for each dialect and each language. The total length is 6 s for one speaker and 90 s for each individual dialect or language.

III. Methodology

The procedure of DR in this study adopts the use of three sets of features, which are MFCC, LPC, and LBP. Individual feature sets and their fusions at the feature level feed a pairwise based support vector machine classifier, with linear kernel function and sequential minimal optimization optimization method. The protocol used in this study use the whole set of the data and validate them using leave one sample out validation approach. Fusion at the feature level for a couple sets of feature and the whole sets of features is computed. To visualize the relation between the classes, confusion matrix (CM) a no-metric multi-dimensional scaling (NMDS) is adopted. NMDS is an optimization procedure that aims to estimate the non-metric relations between different objects. To show the significance of the improvement, a chi-square test is used and p value is computed for each comparison made between the results.

IV. Result and Discussion

Using the method presented in the past section, experiments are conducted for the three different types of feature (MFCC, LPC, and LBP) and their fusion at the feature level. Table I shows the obtained recognition accuracy for both Kurdish dialects and the involved languages. Based on the phonetic characteristic of the MFCC and LPC features, we can observe how both of these features are similarly contribute in dialect and language recognition. While the pattern regarding the LPB feature, which reflects the style characteristic of the speech signal, is totally different between the Kurdish dialects recognition from one side and the languages recognition from the other sides (76-46%). This could be interpreted by the observation that the dialects of the same language are mostly different in style of the speech, while the languages are phonetically different.

In the other hand, from the fusion-based experiments, it can be clearly observed how the LBP fusion with both MFCC and LPC can significantly improve the recognition accuracy for Kurdish dialects (from 71% to 88.9% with p=5.1E-9, and from 78% to 89.6% with p=0.001, for both MFCC and LPC, respectively) and also for Language recognition (from 67.8% to 73% with p=0.02 and from 71.8% to 81.1% with p=0.002 with both of MFCC and LPC, respectively). This improvement reflects the complementarity characteristic of the LBP feature to the widely used phonetic based features (MFCC and LPC in this study). This complementarity of LBP to both MFCC and LPC is also supported by the non-improved recognition accuracy when MFCC and LPC are fused. The best result obtained for dialect and language recognition obtained by fusing LPC and LBP features.

The second aim of this study is to show how close each Kurdish dialect to the neighbor languages as an attempt to study the influence of the neighbor languages and the Kurdish dialects on each other from a phonetic and style based of view. For this purpose, CM of the accuracy results is used and visualized by an NMDS technique using SPSS software. The CM of the highest result obtained by fusing LPC and LBP and the visualized form using NMDS are shown in Table II and Fig. 2, respectively.

This study suggests to interpret the relations and the influence of different languages and dialects through the CM of the recognition procedure.

From Fig. 2, we can clearly observe that the Kurdish dialects are clustered in the top of the graph such that it can

TABLE I
Recognition accuracy (%) of experiments using various features and their fusions

Feature sets	Kurdish DR accuracy	Languages DR accuracy
MFCC	71	67.8
LPC	78	71.8
LBP	76	46
LBP-MFCC	88.9	73
LBP-LPC	89.6	81.1
LPC-MFCC	74.8	70
ALL	88.2	80

MFCC: Mel frequency cypstrum coefficients, LPC: Linear prediction coefficients, LBP: Local binary pattern, DR: Dialect recognition

TABLE II
CM for the whole involved classes using LBP and LPC features

LBP_LPC	Sorani	Hawrami	Badini	Arabic	Persian	Turkish
Sorani	36	3	5	1	0	0
Hawrami	2	39	0	2	2	0
Badini	2	0	40	3	0	0
Arabic	4	0	2	36	0	3
Persian	1	2	0	0	38	4
Turkish	7	0	0	2	6	30

CM: Confusion matrix, LPC: Linear prediction coefficients, LBP: Local binary pattern

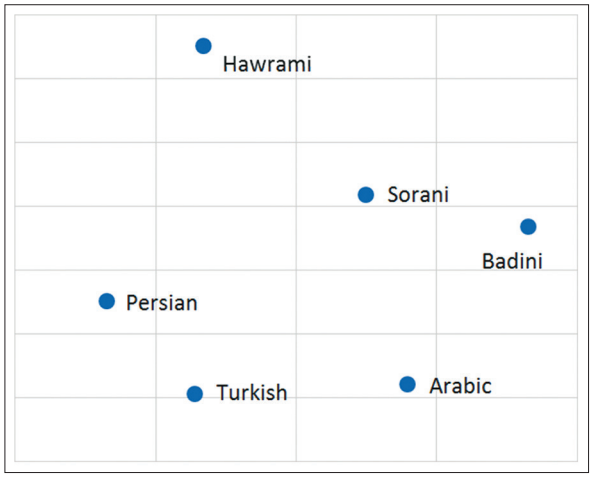

Fig. 2. No-metric multi-dimensional scaling figure for the confusion matrix shown in Table II.

be separated linearly from the involved languages. Another observation is that the Sorani and Badiny dialects are closer to each other than the Hawrami dialect and the nearest language to these two dialects is the Arabic language. While the closest language to the Hawrami dialect is the Persian Language.

V. Conclusion

The result obtained in this study shows that the LBP features for DR are useful especially when fused with phonetic based feature like the LPC. The LBP characterizes the speech style, and therefore it is useful for DR more than language recognition. The first contribution of this study is the use of the LBP set of feature for DR, which has not been used so far. The study also contributes in using NMDS to visualize CM to interpret the relations among different languages for future works. For future work, it might be useful to investigate the fusion for more models at the decision level.

VI. Acknowledgment

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Synthesis and Liquid Crystalline Studies of 2,4-bis(4’-n-nonyloxybenzoyloxy)benzylidene-4’’-n-alkoxyaniline

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***Abstract*–In this paper, a series of new Schiff-bases: 2,4-bis (4’-n-nonyloxy -benzoyloxy)benzylidene-4’’-n-alkyloxyaniline (DC_9A_n) were synthesized. The characterization of compounds was achieved through using (ultra violet, infrared, ^{1}H-nuclear magnetic resonance) measurements. This series comprises 10 members differ by the length of n-alkoxy chain (i.e., OC_nH_{2n+1}, n=1-10). Their liquid crystalline properties were studied using differential scanning calorimetry and polarizing optical microscopy. The lower series such as n=1-3 are purely nematogenic liquid crystals, but the other means (n=4-7) have nematic and smectic phases (S_mC and S_mA). The higher members (n=8-10) are purely smectogenic liquid crystals.**

***Index Terms*—Liquid Crystals, Schiff-bases, Nematic, Smectic.**

I. Introduction

The geometric shape of the molecules, thereby influencing the type of mesophase, the transition temperatures, and the dielectric constant and other properties of the mesogens (Ha, et al., 2010). Aromatic azomethine ester comprising different polarity of substituents has been known to either promote or suppress the mesomorphic properties (Lee, et al., 2010). The aromatic esters are known for their thermal stability, easy synthesis, and relative resistance to hydrolysis (Sandhya, 2014). The molecular breadth is usually derived from a lateral substitution. Lateral substitution plays an effective role in the mesomorphic properties of the compound. However, some Schiff-base–ester liquid crystal compounds have been studied, in different structures and mesophases. Baumeister, et al. (1990) synthesized a compound 4-ethoxy-2′-(4-ethoxy-phenyliminomethyl)-4’-(4-methoxybenzoyloxy) azobenzene with the observation of the nematic (N) phase. Same feature was observed in the study done by Diele, et al., 1991, where the N and S_mA phases were been observed. Berdague, et al. (1993) reported new laterally aromatic branched liquid crystal (LC) materials with the N and S_mC phases. In another study done by Haddawi, et al. (1994) about the lateral aryl substituents, the synthesized compound shows the N and S_mA phases. Aziz (2000) synthesize some new Schiff-base–diester compounds, during this study, the mesomorphic behavior of the Schiff-base compounds shows the N, S_mC, and S_mI mesophases (Fig. 1) with m=6, 8, 10, 12. The aims of this work are synthesize a homologous series of Schiff-base–diester compounds (DC_9A_n) were m=9 and n=1-10, and study their liquid crystalline behavior (Fig. 1).

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II. Measurements and Materials

A. Measurements

Melting points of the compounds were measured using digital (BUCHI B-540) melting apparatus with zooming function. Ultraviolet–visible (UV-Vis) spectra of the compounds were measured over the wavelength range 200-800 nm using chloroform as a solvent, using Agilent Cary 100 UV-Vis instrument. Infrared spectra of the compounds were recovered over the frequency range 400-4000/cm by FTIR-SHIMADZU instruments. The samples were prepared in KBr pellet form. ^{1}H-nuclear magnetic resonance (NMR)-Bruker (400 MHZ) Ultrashield was used for analyzing the ^{1}H-NMR spectra of compounds. The samples were dissolved in deuterated chloroform ($CDCl_3$) at room temperature (298 K). Tetramethylsilane was used as internal standard. The final products were tested for ^{1}H-NMR at the range of the chemical shift (δ=0.0-17.0) ppm. Differential scanning calorimetry (DSC) measurements of transition temperatures of the various liquid crystal phases and calculation of the enthalpy change were carried out using DSC-60 SHIMADZU. The various liquid crystalline

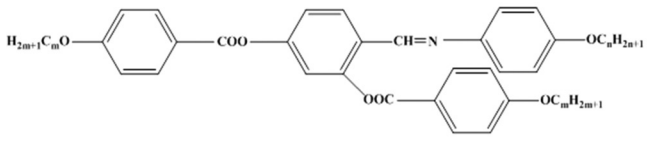

Fig. 1. The general structure of studied compound 2,4-bis(4’-n-alkyloxybenzoyloxy)benzylidene-4’’-n-alkyloxyaniline

textures of the compounds throughout the investigations of all compounds were taken by the high-resolution digital camera equipped with the Leica DM750P polarized optical microscope coupled with Linkam heating-cooling stage.

B. Materials

4-hydroxyacetanilide, tetrahydrofuran (THF), triethylamine (Et_3N), anhydrous magnesium sulfate, benzene, absolute ethanol (Aldrich), n-alkyl bromide, thionyl chloride (Fluka), potassium hydroxide (KOH), 4-hydroxybenzoic acid, hydrochloric acid (HCl), sodium carbonate, and glacial acetic acid (Scharlau) were used as received.

C. Synthesis

4-n-nonyloxybenzoic Acid (C_9)

4-hydroxybenzoic acid (50 mmol, 6.900 g), n-nonyl bromide (55 mmol), and potassium hydroxide (KOH 110 mmol, 6.160 g) were dissolved in ethanol/water 160/16 mL in a round-bottom flask fitted with a reflux condenser and refluxed the mixture on hot plate with magnetic stirrer for 24 h. A 60 ml (20%) of KOH was added to the reaction mixture, and reflux was continued for 5 h. The solution was cooled to room temperature and the reaction mixture was acidified by adding ice cooled (2M, HCl), and the formed white precipitate was filtered and washed with water until the filtrate became neutral. The crude product was dried in vacuum oven, and then, recrystallized in ethanol (absolute) until constant transition temperature is obtained (Cativiela, et al., 1995) which was 144°C and agrees with the values by Dave and Vora, (1970) and Keller and Liebert (1978) and it almost similar to reported value (Isotropic point=144°C). (Yield: 85%).

4-n-nonyloxy Benzoylchloride

Thionyl chloride $SOCl_2$ (150 mmol) and 4-n-nonyloxybenzoic acid (100 mmol) were dissolved in dry benzene (75 mL), and the resulting solution was refluxed until the evolution of HCl and SO_2 ceases, after refluxing for 3 h the reaction is ended. The excess of thionylchloride was removed on rotary evaporator to give the product. The yield was 98% in most cases. The acid chloride is very sensitive to moisture and it has been used immediately after synthesis without any purification for the synthesis of 2,4-bis(4'-n-nonyloxybenzoyloxy) benzaldehyde in the next step (Dave and Vora, 1970; Keller and Liebert, 1978).

Synthesis of 2,4-bis(4'-n-nonyloxybenzoyloxy) Benzaldehyde (DC_9)

A solution of 2,4-dihydroxybenzaldehyde (3 g, 22 mmol) in 20 mL THF was added dropwise to a mixture of 4-n-nonyloxybenzoyl chloride (14.1 g, 50 mmol) in 500 mL THF and 7.4 mL of triethy1amine (Et_3N) with vigorous stirring at 10°C in an ice bath. After the addition, the reaction was allowed to reach room temperature and stirred for 38 h. The precipitate product and the triethylamine-HC1 salt were then poured into 500 mL cold water. The resulting precipitate was filtered and washed with water, and 500 mL, 5% Na_2CO_3 solution and then water until the filtrate became neutral, and the product was dried (Pugh and Schrock, 1992; Zhou, et al., 1988), Finally, recrystallized by ethanol (absolute) to yield 79% of product with melting point (47-49°C).

4-n-alkyloxyacetanilides (AA_n)

4-hydroxyacetanilide (100 mmol) was dissolved in 75 mL of hot ethanol with stirring and then cooled. After cooling, a solution of 5 mL, 125 mmol KOH is added slowly, followed by dropwise addition of 110 mmol n-alkyl bromide in 25 mL of in ethanol. The mixture was refluxed for one hour, then, the mixture was cooled to room temperature, and then, 25 mL of water was added with cooling. The resulting white precipitate was filtered off, washed twice or three times with water until the filtrate became neutral, dried in a desiccator, and recrystallized with ethanol/water (75/25 mL) (Keller and Liebert, 1978). Yield (69-88%).

4-n-alkyloxyanilines (A_n)

4-n-alkyloxyacetanilide (50 mmol) in 50 mL of ethanol was refluxed, and then, during the reflux (12.5 mL, 20 N), KOH was added dropwise, and then, reflux was continued for 5 h. Ethanol was removed using rotary evaporator, and the residue (A_n) was extracted twice with 50 mL of benzene using centrifuge technique. The combined organic layers were washed with water for neutralization and then dried using anhydrous magnesium sulfate. The solvent (benzene) was removed using rotary evaporator to give the products (A1-A10) (Yield: 78-85%) (Keller and Liebert, 1978).

Synthesis of Schiff-bases

0.2 mmol of DC_9, 0.2 mmol of A_n, and few drops of glacial acetic acid as catalyst in 10 mL of ethanol (absolute) were refluxed for 6-7 h. The yellow precipitate formed during the cooling of mixture, it was filtered off, washed 2 or 3 times with cold ethanol. Finally, recrystallized in ethanol (absolute) until the transition temperature remains constant. Yield (69-72%).

III. Spectroscopic Identification

A. UV Spectra Measurements of Schiff-bases

The UV-Vis spectra of the compounds (DC_9A_n) were studied in chloroform as a solvent. The Schiff-bases shows similar UV spectra. These compounds characterized by the appearance of three bands between 200 and 500 nm (Silverstein, et al., 1974). The first band appears with λmax. of 260-263 nm, attributed to transitions of excited electrons from π-π* in aromatic rings. The second band is shoulder, appears at 343-348 nm, attributed to transitions of excited electrons from π-π* in aniline ring. The third band appears at 350-356 nm, attributed to transitions of excited electrons from n-π* (Aziz, 2000).

B. Fourier Transform Infrared Spectra Measurements

C_9: 2400-3300 cm^{-1} (O-H) stretching (str.), 1678/cm ($C=O_{str.}$), 1604/cm ($C=C_{str.}$), 2856-2954/cm and 3050-3080/cm ($-C-H_{str.}$) and ($=C-H_{str.}$), respectively, 1261/cm ($C-O-C_{str.}$).

DC_9: 1722/cm ($C=O_{str}$) (Ester), 1686/cm ($C=O_{str.}$) (Aldehyde). 1608/cm ($C=C_{str.}$), 2854/cm and 2916/cm symmetric and asymmetric ($-C-H_{str.}$), respectively, 3070/cm ($=C-H_{str.}$) and 1260/cm ($C-O-C_{str.}$).

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AA_n: 3286-3330/cm ($N-H_{str.}$), 1658-1660/cm ($C=O_{str.}$), 1596-1610/cm ($C=C_{str.}$), 2848-2953/cm and 3065-3075/cm ($C-H_{str.}$) and ($=C-H_{str.}$), respectively. 1532-1554/cm ($N-H_{bending\ (bend.)}$).

A_n: 3312-3420/cm ($N-H_{str.}$), 1516-1518/cm ($N-H_{bend.}$), 2850-2955/cm ($C-H_{str.}$), 3050-3070/cm ($=C-H_{str.}$), 1250/cm ($C-O-C_{str.}$)

DC_9A_n: 1625-1633/cm ($C=N_{str.}$), 1732-1741/cm ($C=O_{str.}$) (Ester). 1605-1608/cm ($C=N_{str.}$), 1570-1580/cm ($C=C_{str.}$). 2850-2954/cm and 3055-3093/cm ($C-H_{str.}$) and ($=C-H_{str.}$), respectively. 1245-1249/cm ($C-O-C_{str.}$).

C. ^{1}H-NMR Measurements

DC_9: s, 1H, at 10.2 ppm. aldehyde group. m, 11H, at 6.96-8.19 ppm. benzene rings. t, 4H, at 4.05-4.09 ppm. –OCH_2 groups. m, 4H, at (1.81-1.87) ppm. two –CH_2 groups neighbor with –OCH_2 groups. m, 24H, at 1.31-1.49 ppm. –CH_2 groups in the terminal groups. t, 6H at 0.9 ppm. –CH_3 groups at the end of terminal groups. DC_9A_1: s, 1H, at 8.7 ppm. imine proton (a). d, 4H, at 8.1-8.19 ppm. benzoate benzene rings (b). d, 2H, at 7.82-7.85 ppm. aniline benzene ring (f) closer to nitrogen atom. s, 1H, at 7.68 ppm. benzylidene ring lying between two ester groups (g). d, 1H, at 7.53-7.58 ppm. benzylidene ring closer to ester group (d). d,1H at 7.38-7.43 ppm. benzylidene ring closer to imine group (e). m, 6H, at 6.5-7.1 ppm. benzene ring closer to –OCH_2 groups (c). m, 4H, at 3.8 ppm. –OCH_2 groups (j). s, 3H, at 4 ppm. -OCH_3 protons (N'). m, 4H, at 1.8-1.86 ppm. two –CH_2 groups which are neighbor with –OCH_2 groups (K). m, 24H, at 1.31-1.5 ppm. other –CH_2 groups in the two other terminal groups (l). t, 6H, at 0.89-0.92 ppm, two other –CH_3 groups in the two other terminal groups (m) (Figs. 2 and 3).

IV. Results and Discussion

A. DSC and Polarizing Optical Microscopy (POM) Studies

DC_9 shows no liquid crystalline mesophases, which was proved by DSC and POM analysis. The DSC of this compound has only one transition corresponding to the transition from crystal (Cr) phase to isotropic (I) phase which takes place at 53.45°C with high change of enthalpy ΔH of transition 132.38 J/mol and high change of entropy ΔS of transition 0.405 J/mol/K The phase transition temperatures and corresponding enthalpy changes ΔH of all Schiff-base compounds determined using DSC and POM are summarized in Tables I and II. Phase transition temperatures and enthalpy changes were measured at heating rates (20 C/min). DSC heating curves of the compounds DC_9A_1 and DC_9A_6 as representative examples are shown in Figs. 4 and 5. All compounds exhibited liquid-crystalline properties. DSC studies revealed that the differences in liquid-crystalline properties of all compounds along with increasing length of aliphatic chain are clearly observed.

B. Phase Transition Temperatures Against Number of Carbon

The S_mA phase range T_{SmA-I} increased linearly for n=8-10, and increases drastically to 42°C, for n=10 during heating. We assume that competing effects of vibrational motions and attractive forces in the alkyloxy chains occur in the S_mA

TABLE I
Phase Transition Temperatures/°C Taken by POM Schief-bases Enthalpy Changes with Mesophase Thermal Stability Ranges (ΔT_M)

Compound	Enthalpy change (ΔH) in (J/mol)				
	Transitions				
	Cr-Cr	Cr-N, Cr-S_mC	Total (ΔH) for Cr-mesophase	S_mC-S_mA	S_mC-N, S_mA-N
DC_9A_1	41.74	79.1	120.84		
DC_9A_2	22.81	47.07	69.88		
DC_9A_3	49.14 10.35	12.71	72.2		
DC_9A_4		61.38	61.38		Not recorded on DSC curve
DC_9A_5		68.7	68.7		2.68
DC_9A_6	10.5	28.94	39.44		15.28
DC_9A_7		17.22	17.22	8.86	1.87
DC_9A_8		55.89	55.89	3.28	
DC_9A_9	20.4	2.27	22.67	4.69	
DC_9A_{10}		17.17	17.17	3.36	

DSC: Differential scanning calorimetry, POM: Polarizing optical microscopy

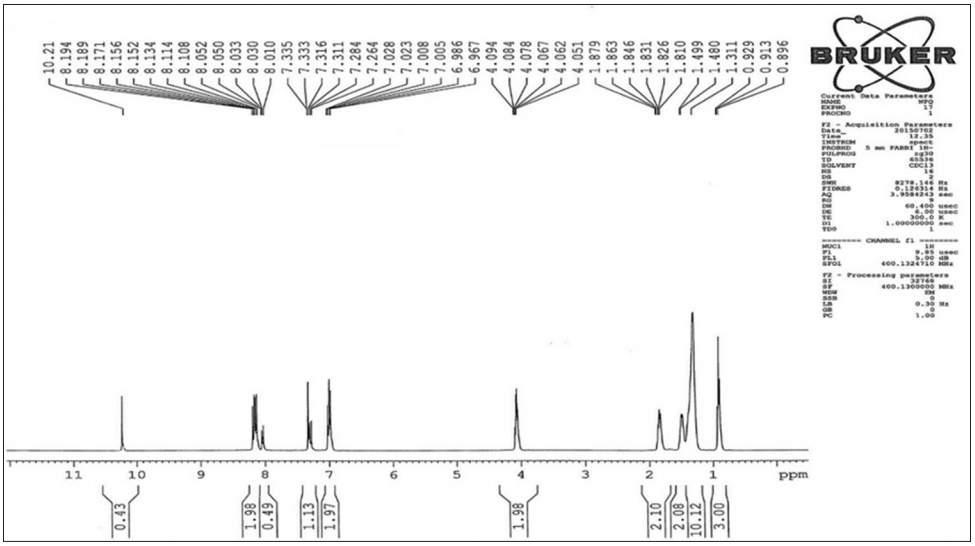

Fig. 2. Full ^{1}H-nuclear magnetic resonance spectrum of 2,4-bis(4'-n-nonyloxybenzoyloxy) benzaldehyde (DC_9)

TABLE II
ENTHALPY CHANGES OF TRANSITIONS FOR SCHIEF-BASES

Compound	Cr-Cr	S_mC		S_mA		N		I		ΔT_m
	DSC	DSC	POM	DSC	POM	DSC	POM	DSC	POM	POM
DC_9A_1	96.69					150.49	112		155	43
DC_9A_2	109.15					153.88	127		167	40
DC_9A_3	67.83 110.01					134.37	112		143	31
DC_9A_4		66.72	55				77		93	38
DC_9A_5		63.51	48			88.10	78		104	56
DC_9A_6	61.10 66.69	100.19	92			135.98	115		150	59
DC_9A_7		101.18	90	130.20	120	152.85	152		166	76
DC_9A_8		85.20	73	111.54	105				122	49
DC_9A_9	87.69	96.60	85	116.17	112				137	52
DC_9A_{10}		87.00	77	130.36	105				147	70

DSC: Differential scanning calorimetry, POM: Polarizing optical microscopy

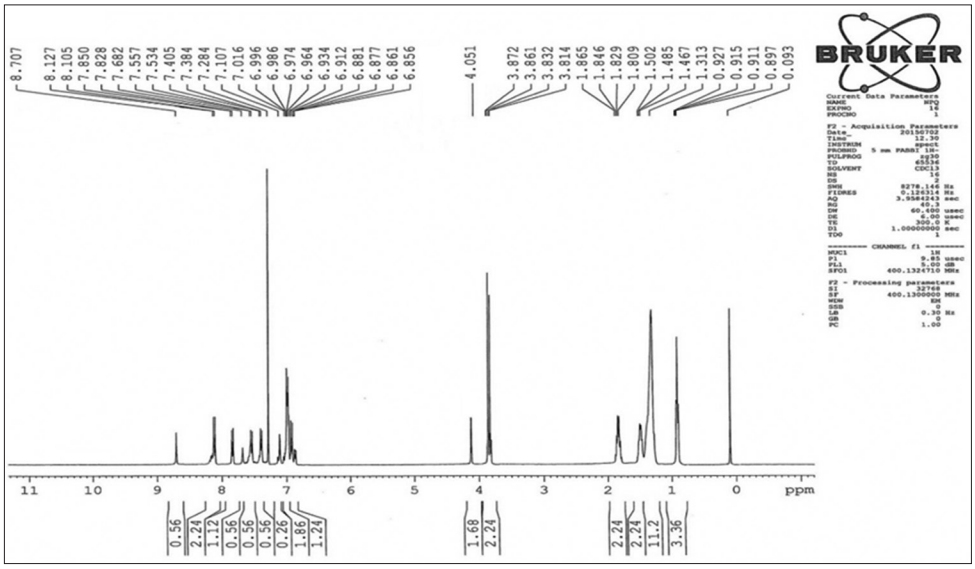

Fig. 3. Full ^{1}H-nuclear magnetic resonance spectrum of DC_9A_1

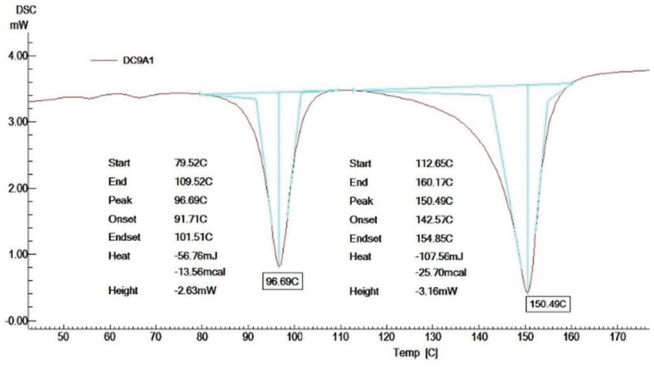

Fig. 4. Heating differential scanning calorimetry curve of DC_9A_1

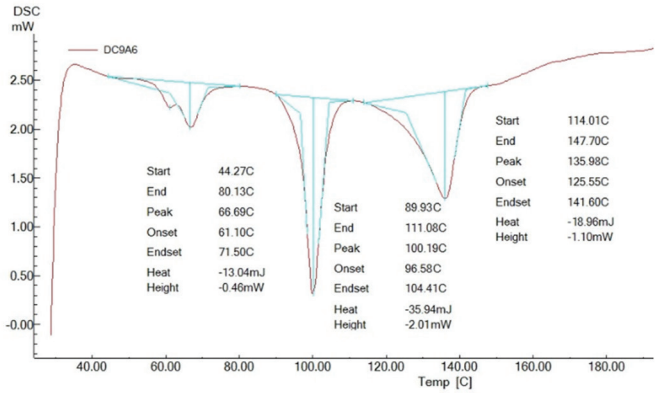

Fig. 5. Heating differential scanning calorimetry curve of DC_9A_6

phase. When chain length reaches 10 (decyl), the alkyloxy chain attractive forces substantially outweigh the chain vibrational motions, resulting in the formation of a long-range of S_mA phase. Conversely, short alkyloxy chain lengths (n=8) tend to disrupt lamellar packing. For S_mC-S_mA transition, the curve is very regular for the last four compounds where n=7-10 which show an odd-even effect phenomena, in which the compounds with odd number of carbon atoms has higher ($T_{SmC-SmA}$) than the compounds with even number of carbon atoms. For Cr-S_mC transition, the curve is very regular for n=4-7 with odd-even effect phenomena, in which the compounds which show an odd number of carbon atoms has lower (T_{Cr-SmC}) than the compounds with even number of

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carbon atoms. There is only one transition from S_mA-N for the member (n=7) (Fig. 6).

C. Mesophase Thermal Stability Ranges (ΔTm)

From Table II, it was noted that the widest nematic thermal stability range ΔT_N=43°C which exhibited by the first member (n=1) in the series. The widest smectic thermal stability range ΔT_{Sm}=70°C in the last member (n=10) in the series.

D. Enthalpy and Entropy of Transitions

The total enthalpy or entropy change of crystal (Cr) to liquid crystal phase (N or S_mC) transition is very regular for the first six compounds where n=1-6 in the series which shows an odd-even effect phenomena, in which the compounds with odd number of carbon atoms have higher ΔH and ΔS value than the compounds with even number of carbon atoms. The enthalpy or entropy change of S_mC-S_mA transition is very regular for the past four compounds where n=6-10 in the series which shows an odd-even effect phenomena, in which the compounds with odd number of carbon atoms have higher ΔH and ΔS value than the compounds with even number of carbon atoms. The enthalpy or entropy change of S_mC-N and S_mA-N transition is very regular for the members (n=5-7) in the series which shows an odd-even effect phenomena, in which the compounds with odd number of carbon atoms (n=5 and 7) have lower ΔH and ΔS value than the compound with even number of carbon atoms. The value of Enthalpy or entropy change for S_mA-N transition when n=7 is lower than the value of enthalpy or entropy change for S_mC-N transition when n=5 and 6.

E. Liquid Crystal Textures

Nematic Phase Textures

The (N) phase generally exhibits a thread-like texture; this is confirmed by the schlieren texture of the NLC (Fig. 7) and the droplet texture (Fig. 8). The schlieren texture shows dark brushes, which correspond to the extinction orientation of the NLC. Accordingly, the director (n)^ lies either parallel or perpendicular to the polarizer axes. The points, where two or four brushes meet, correspond to the director singularities and are called disclinations in the structure.

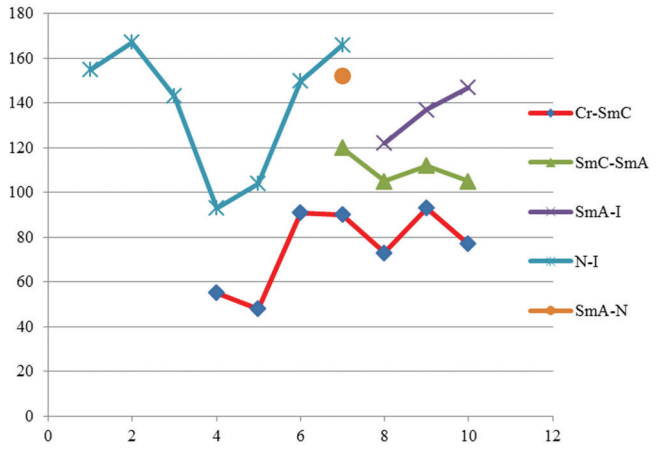

Fig. 6. The dependence of the transition temperatures taken by polarizing optical microscopy on the number of carbon atoms (n) in the terminal alkyloxy chains for DC_9A_n

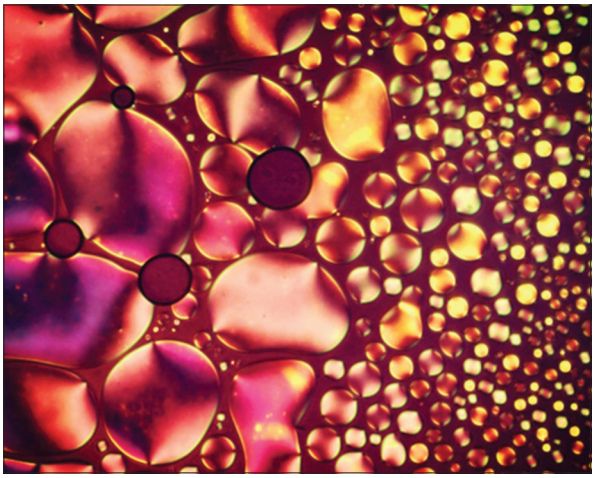

Fig. 8. The optical texture exhibited by DC_9A_1 on cooling from isotropic liquid, Nematic droplets near isotropic transition point at 150°C

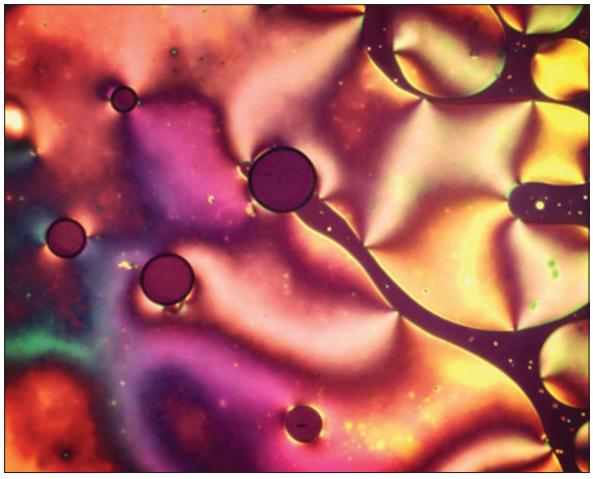

Fig. 7. The optical texture exhibited by DC_9A_1 on heating from crystal phase (Cr_2), the Schlieren texture of the (N) phase at 140°C

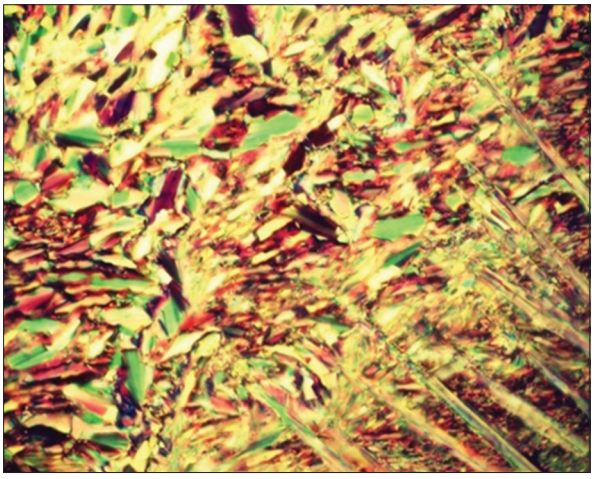

Fig. 9. The optical textures exhibited by DC_9A_6 on heating from crystal phase, the typical broken focal-conic fan texture of the S_mC phase at 105°C

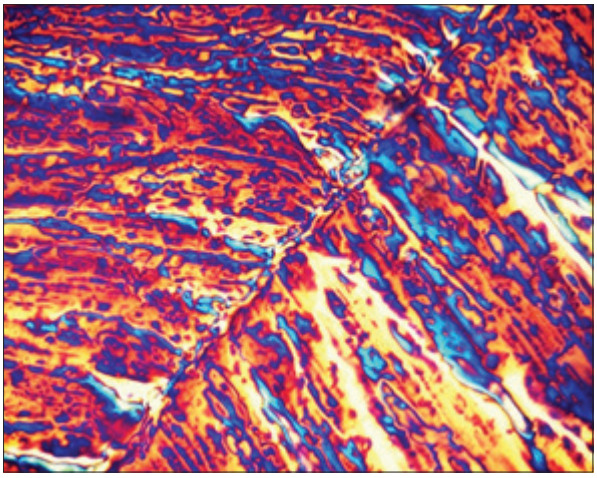

Fig. 10. The optical textures exhibited by DC_9A_7 on heating from crystal phase, the typical thread-like (schlieren) texture of the S_mC phase at 103°C

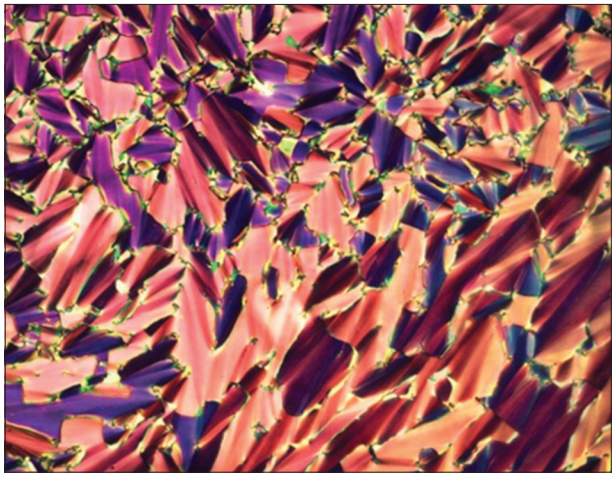

Fig. 11. The optical textures exhibited by DC_9A_7 on heating from S_mC phase, the typical focal-conic fan texture of the S_mA phase at 131.1°C

Smectic Phase Textures

S_mC phase exhibits the broken focal-conic fan shaped (Fig. 9) and schlieren texture (Fig. 10). S_mA phase exhibits the focal-conic fan shaped (Fig. 11) and batonnet textures.

V. Conclusion

Synthesis of a series of new Schiff-base–ester compounds and study their liquid crystalline behavior. From the obtained result, it can be concluded that, when more than one mesophase is possible, the smectic state increases in thermal stability, at the expense of the nematic, as chain length increases. It is often seen that, while the lower homologs are purely nematogenic (LCs) as in DC_9A_1, DC_9A_2 and DC_9A_3, the higher are purely smectogenic (LCs) (disappearance of the nematic phase) as in DC_9A_8, DC_9A_9 and DC_9A_{10}, and the intermediate homologs exhibit both mesophases (nematic and smectic phases) as in DC_9A_4, DC_9A_5, DC_9A_6 and DC_9A_7. Furthermore, it can be concluded that 2,4-bis(4'-n-nonyloxybenzoyloxy) benzaldehyde (DC_9) is not liquid crystalline compound.

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Ultrasound-assisted Synthesis of Some New Curcumin Analogs and Their Corresponding Pyrazoline Derivatives

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***Abstract*–In this work, a series of new curcumin mono-carbonyl analogs containing benzyloxy moieties and their pyrazoline derivatives were synthesized using a green method (ultrasound assisted technique) along with traditional method. The work also includes a comparison between the two methods together and with the reported results. Remarkable improvements were achieved by dropping down the reaction time from hours to minutes and obtaining higher yields of the products.**

***Index Terms*—Curcumin, Mono carbonyl curcumins, Pyrazoline, Ultrasound.**

1. Introduction

According to the high clash of the micro-organisms against typical antibiotics and low reactivity of communal antibiotics, there is an actual need for the innovation of new compounds and encourage chemists developing new biologically active compounds with higher antimicrobial activities and lower risks.

Scientific researches that exceed four decades have approved the diverse pharmacological influence of curcumin and established its ability to act as a chemopreventive agent as well as a potential therapeutic agent against several chronic diseases (Priyadarsini, 2014). Curcumin (bis-α, β-unsaturated diketone) has an interesting structure with two phenolic groups and one active methylene function, which are potential sites for attaching biomolecules.

Curcumin is a natural yellow bioactive pigment which obtained from rhizomes of plant *Curcuma longa*, a member of the Zingiberaceae (ginger) family (Priyadarsini, 2014, and Shishodia, et al., 2005). Curcumin was first isolated from the plant *C. longa* in 1815 (Vogel and Pelletier, 1815), its structure as diferuloylmethane was determined in 1910 and first synthesis in 1937 started from the chloride of the carbometoxyferuloic acid was achieved by Paban, 1937. After the discovering, its potential anticancer effect of curcumin which was report by Singh and Aggarwal (1995), considerable attention has been focused to date on curcumin and its analogs including synthesis using different methods (Lei, et al., 2011; Li, et al., 2016), structure modification (Haneefa, et al., 2014; Wang, et al., 2016), biological and pharmacological effects such as: Anti-inflammatory (Zhao, et al., 2010), antioxidant (Bayomi, et al., 2013; Selvam, et al., 2005), antitumor anti-cancer (Pan, et al., 2016; Das and Chakraborty, 2016), antimalarial (Manohar, et al., 2013), antidiabetic activity (Konatham, et al., 2010), and highly potent antiparasitic activities (Din, et al., 2016). Curcumin is also used as flavor and food coloring-materials, used as environmental dye; it is known as Natural yellow 3 and is assigned E100 number (Grynkiewicz and Slifirski, 2012). Mono carbonyl analogs of curcumin can be converted to heterocyclic compounds via cyclization of α,β-unsaturated carbonyl moieties with hydrazine hydrate and other cyclizing agents (Shim, et al., 2002).

Herein, we have described a green method (ultrasound technique) besides a traditional method to synthesize some new mono carbonyl curcumin analogues, and their cyclic products along with comparison between the two methods together and with previous reports.

II. Material and Methods

A. Experimental Notes

Melting Points were determined by a Stuart Scientific melting point apparatus (SMP3). IR-Spectra were recorded on a SHIMADZU, Fourier Transform-Infrared spectroscopy Mod IR Affinity-1 CE, in which solid materials were taken as a disc KBr special for spectroscopy. The ^{1}H-nuclear magnetic resonance (NMR) and ^{13}C-NMR were taken on a Bruker 400 MHz ultra-shield with TMS as internal references.

B. Preparation of Benzyloxy-Benzaldehydes (1a-e)

Benzyloxy-benzaldehydes (1a-e) have been prepared according to reported procedure (Nagaini, et al., 2009).

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The ppt. was recrystallized from ethanol, the physical properties of the prepared substituted benzyloxy-benzaldehydes (1a-e) where outlined in Table I.

C. Synthesis of 1, 5-bis (o,m, or p-(substitutedbenzyloxy) phenyl)penta-1,4-dien-3-one (2a-e)

Classical Method: 1,5-bis(4-(3-nitrobenzyloxy)phenyl)penta-1,4-dien-3-one (2a)

Mono carbonyl analog of curcumin (2a) was synthesized by mixing acetone (0.14 g, 2.5 mmol), 4-(3-nitrobenzolxy) benzaldehyde (5 mmol) and sodium hydroxide (0.2 g, 5 mmol) in ethanol (20 mL). The mixture was refluxed for (3 h) until all starting materials had reacted, which was monitored by the formation of red color in testing with drops of H_2SO_4. The cooled mixture was solidified and filtered off, dried and recrystallized from ethanol to give pure yellow crystals of curcumin analog (2a), 0.63 g 84% (Shah, 2010).

Ultrasound Assisted Synthesis Method (Chen, et al., 2004)

A mixture of acetone (0.14 g, 2.5 mmol), sodium hydroxide (0.2 g, 5 mmol), and substituted benzaldehydes (5 mmol) in ethanol (20 mL) was irradiated in the water bath ultrasonic cleaner at room temperature for 5-10 min, until all starting materials had reacted, the reaction proceeded as in *a*. The results were tabulated in Table II.

D. (o,m,p-(substitutedbenzyloxy)phenyl)-3-(o,m,p-(substitutedbenzyloxy) styryl)-2-pyrazoline (3a-e)

Classical Method (Hawaiz and Samad, 2012)

A mixture of newly prepared curcumin analogues (2a-e) (1 mmol), hydrazine hydrate (2 mmoles) and sodium hydroxide (0.1 g, 2.5 mmol) in methanol (20 mL) was refluxed with stirring for (3-4 h) until complete the reaction which was monitored by change the color to green in testing with drops of H_2SO_4. The ppt. was isolated by suction filtration, washed with ethanol, dried and purified by recrystallization from xylene. The physical properties of the prepared pyrazolines (3a-e) are summarized in Table III.

Ultrasound Assisted Synthesis Method (Trilleras, et al., 2013)

A mixture of hydrazine hydrate (2 mmol), curcumin analogous (1 mmol), and sodium hydroxide (0.1 g, 5 mol) in methanol (20 mL) was irradiated for appropriate time at (25-40°C) in a water bath of an ultrasonic cleaner until the disappearance of curcumin analogs indicated by changing the color from yellow to white and monitoring by green color formation in testing with drops of H_2SO_4.

The desired products were separated by suction filtration and washed with water to neutralize and with ethanol, after which purified by recrystallization from xylene. The reaction time, m.p. and the percentage of yields are listed in Table III.

TABLE I
SOME PHYSICAL PROPERTIES OF PREPARED BENZYLOXY BENZALDEHYDES (1A-E)

Comp.	R	Molecular formula	Yield%	M.P./C	Time hrs
1_a	4-(3-NO_2-C_6H_4-CH_2-O-)	$C_{15}H_{13}NO_4$	83	84-86°C	4
1_b	4-O-CH_2-C_6H_5	$C_{15}H_{14}O_2$	85	71-73°C	5
1_c	3-O-CH_2-C_6H_5	$C_{15}H_{14}O_2$	83	60-62°C	6
1_d	2-(4-Cl-C_6H_4-CH_2-O-)	$C_{15}H_{13}ClO_2$	85	82-83°C	5.5
1_e	2-(3-NO_2-C_6H_4-CH_2-O-)	$C_{15}H_{13}NO_4$	79	124-126°C	4

TABLE II
SOME PHYSICAL PROPERTIES OF PREPARED MONO-CARBONYL ANALOGUES OF CURCUMIN (2A-E)

Comp.	R	Molecular formula	Yield%	M.P./°C	Time min.
2_a	4-(3-NO_2-C_6H_4-CH_2-O-)	$C_{31}H_{24}N_2O_7$	173-175°C	95 84 classic	5
2_b	4-O-CH_2-C_6H_5	$C_{31}H_{26}O_3$	179-180°C	90	10
2_c	3-O-CH_2-C_6H_5	$C_{31}H_{26}O_3$	98-99°C	86	10
2_d	2-(4-Cl-C_6H_4-CH_2-O-)	$C_{31}H_{24}Cl_2O_3$	121-124°C	89	8
2_e	2-(3-NO_2-C_6H_4-CH_2-O-)	$C_{31}H_{24}N_2O_7$	151-153°C	88	5

TABLE III
SOME PHYSICAL PROPERTIES OF THE PREPARED CYCLIZED CURCUMIN ANALOGUES (3A-E)

Comp.	R	Molecular formula	M.P./°C	Yield % Ultra 1 Classic 2	Time/ Hours Ultra 1 Classic 2
3_a	4-(3-NO_2-C_6H_4-CH_2-O-)	$C_{31}H_{26}N_4O_6$	169-170°C	94 72	1 3
3_b	4-O-CH_2-C_6H_5	$C_{31}H_{28}N_2O_2$	133-134°C	77 79	1 3
3_c	3-O-CH_2-C_6H_5	$C_{31}H_{28}N_2O_2$	232-234°C	80 54	1.25 3.5
3_d	2-(4-Cl-C_6H_4-CH_2-O-)	$C_{31}H_{26}Cl_2N_2O_2$	>300°C	90 80	1 3
3_e	2-(3-NO_2-C_6H_4-CH_2-O-)	$C_{31}H_{26}N_4O_6$	172-173°C	95 93	1.25 4

III. RESULTS AND DISCUSSION

Some new curcumin analogs (2a-e) were synthesized and converted to pyrazolines (3a-e) using different methods and techniques such as traditional method and ultrasound irradiation technique to provide the products in high yields and short reaction times in three main steps as shown in the scheme of Fig. 1.

The exciting improvement was obtained in the formation of newly derivatives of curcumins (2a-e) in using ultrasonic technique by dropping down the reaction time from hours to minutes and increasing the percentages of the products as compared to the traditional methods and literatures (Handayani, et al., 2012).

The formation of the curcumine analogs (2a-e) was confirmed on the basis of their IR, ^{1}H-NMR and ^{13}C-NMR spectral data. In the IR spectra Table IV, the shifting of the absorption band of carbonyl group of the two reactants benzyloxy benzaldehydes and acetone to lower wave numbers 1666-1647/cm is a strong evidence for the formation of conjugated dibenzalacetones (Hussein, et al., 2013).

The ^{1}H-NMR spectra of curcumin analogs (2b-d) (Fig. 2), Table V, show characteristic doublet signals for α, β- protons at (7-8) ppm, which overlapped with aromatic protons. Obviously, in all cases, the doublet for (H_β) appear

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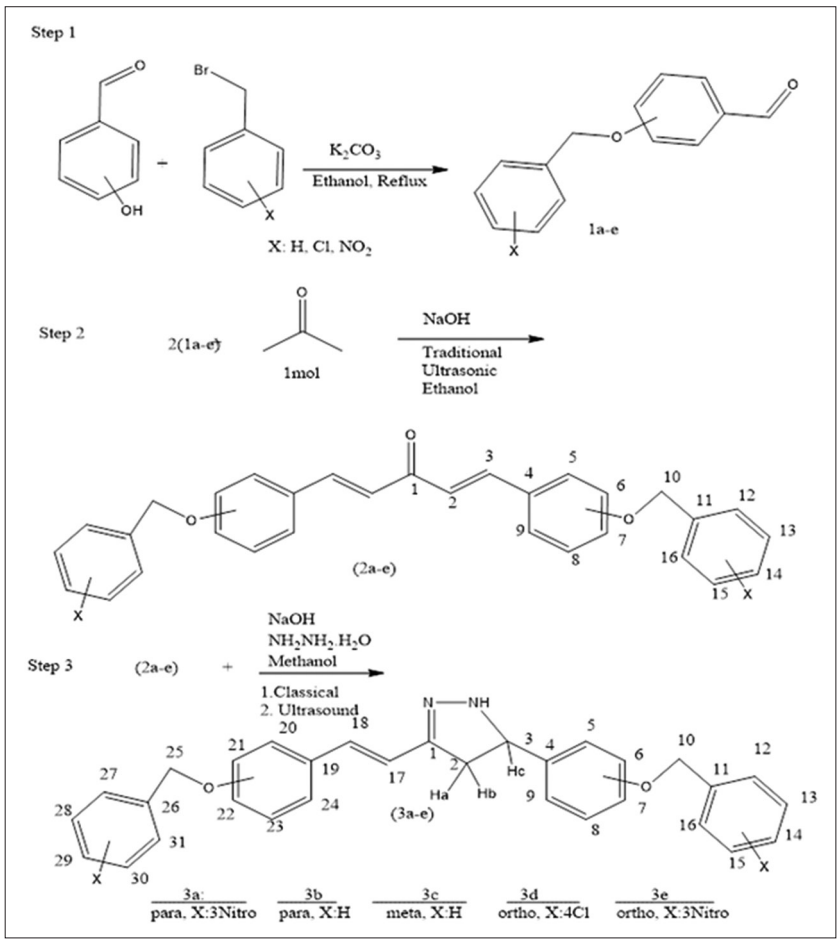

Fig. 1. Synthesis of curcumin mono-carbonyl compounds and their purazloine products.

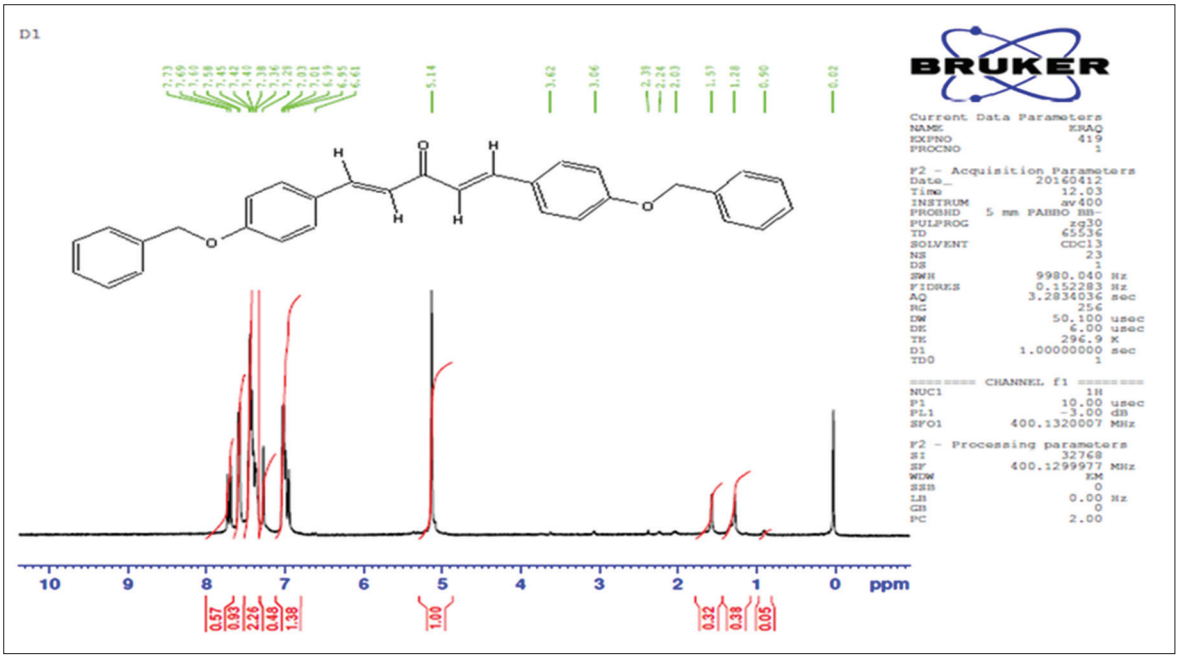

Fig. 2. The [1]H-nuclear magnetic resonance spectrum of compound 2b.

at higher wave numbers than aromatic protons, while the (H_α) completely mixed with aromatic protons; it is hard to distinguish it at a fixed number (Hussein, 2014). The [1]H-NMR spectrum of all compounds showed a singlet signal at 5.1 ppm related to the two protons of -O-CH_2 of benzyloxy group, and a doublet at 7.7 ppm corresponding to CH_β proton,

a multiplete at 6.9-7.5 ppm which contain H_α and protons of two phenyl rings; this is a good confirmation for the expected products. Further support for structure elucidation is come from ^{13}C-NMR spectra (Fig. 3) Table VI, assignment of carbon atoms presented in mono-carbonyl analogs, showed a characteristic peak related to the β-C atom approximately at (140) ppm which is more de-shielded than that of α-C atom nearly around δ (123) (Hawaiz, et al., 2012). The number of signals fitted with number carbon types of the expected desired products as shown in Table VI.

TABLE IV
Assignment of Characteristic Frequencies (cm^{-1}) of IR Spectra for The Prepared Compounds (1a-e, 2a-e and 3a-e)

Prod.	Benzyloxy-benzaldehyde (1a-e)		Curcumin analogs (2a-e)		Pyrazoline (3a-e)	
	C=Ostr.	C=Cstr.	C=Ostr.	C=Cstr.	N-Hstr.	C=C, C=N
a	1687	1601	1647	1618,1602	3340	1606
b	1683	1600	1653	1627, 1593	3327	1600
c	1680	1603	1653	1629,1595	3340	1598
d	1681	1600	1651	1616, 1593	3342	1600
e	1681	1598	1666	1612, 1596	3325	1598

TABLE V
The ^{1}H-NMR Data for The Prepared Curcumin Analogs (2 b, c, d) and Pyrazoline (3b): Solvent $CDCl_3$

Product	δ/ppm	Multiplicity	Intensity	Assignment
2 b	5.14	s	2H	-O-CH_2-H_{10}
	6.95-7.6	m	10H	Ar-H-[H_2,+ 2Ar ring H]
	7.73	d	1H	H3-β-proton
2 c	5.1	s	2H	-O-CH_2-H_{10}
	7.01-7.4	m	10H	Ar-H-[H_2,+ 2Ar ring H]
	7.7	d	1H	H3-β-proton
2 d	5.1	s	2H	-O-CH_2-H_{10}
	6.93-7.50	m	10H	Ar-H-[H_2,+ 2Ar ring H]
	8.05	d	1H	H3-β-proton
3 b	2.87	dd	1H	Ha
	3.27	dd	1H	Hb
	4.81	dd	1H	Hc
	5.07	s	2H	-O-CH_2-$H_{10,25}$
	5.86	d	1H	H_{17}
	6.58	d	1H	H_{18}
	6.98-7.4	m	18H	4Ar-H-ring proton

NMR: Nuclear magnetic resonance

TABLE VI
The ^{13}C-NMR Data for The Prepared Curcumin Analogs (2 b, c, d) and Pyrazoline (3b): Solvent $CDCl_3$.

^{13}C-NMR							
2 b		2 c		2 d		3 b	
δ/ppm	Assign.	δ/ppm	Assign.	δ/ppm	Assign.	δ/ppm	Assign.
70.29	C_{10}	70.25	C_{10}	69.81	C_{10}	40.11	C_2
115.47	$C_{6,8}$	114.43	C_5	112.9	C_6	63.82	C_3
123.79	C_2	117.3	C_7	121.52	C_4	70.19	$C_{10,25}$
127.61	$C_{12,16}$	121.49	C_9	124.5	C_8	115.29	$C_{6,8,21,23}$
128.05	$C_{5,9}$	125.81	C_2	126.66	C_2	120.30	C_{17}
128.31	C_4	127.6	$C_{12,16}$	128.68	C_9	127.58	$C_{12,16,27,31}$
128.83	C_{14}	128.23	C_{14}	129.02	$C_{13,15}$	128.09	$C_{14,19,29}$
130.23	$C_{13,15}$	128.78	$C_{13,15}$	131.65	C_7	128.72	$C_{20,24}$
136.62	C_{11}	130.11	C_8	133.97	C_{14}	129.79	$C_{5,9}$
142.76	C_3	136.33	C_4	135.23	C_{11}	133.00	$C_{13,15,28,30}$
160.88	C_7	136.75	C_{11}	138.22	C_3	135.32	C_4
189.6	C_1	143.31	C_3	157.50	C_5	136.92	C_{18}
		159.27	C_6	190.14	C_1	137.06	$C_{11,26}$
		188.87	C_1			152.93	C_1
						158.53	C_7
						159.04	C_{22}

NMR: Nuclear magnetic resonance

Pyrazolines (3a-e) have been synthesized on the basis of Claisen or Michael addition reactions of hydrazine hydrate on the prepared mono-carbonyl analogs (2a-e) by utilizing classical and ultrasound irradiation method in the presence of sodium hydroxide in methanol. Considerable improvement has been focused on the comparison of the results with the literature and the two efficient methods together. El-Rayyes and Al-Johary (1985) prepared similar pyrazolines in several hours, Pinto, et al., 2003, also prepared bis-pyrazoline in 24 h (Pinto, et al., 2003). While, in this work, products were obtained in good yields and shorter reaction times, about 60 min in ultrasound method. This demonstrates the notability of ultrasound over classical refluxing method.

The structures of the synthesized compounds (3a-e) were assigned on the basis of spectral data. In the IR spectra Table IV, the appearance of a sharp band at 3320/cm attributed to N-H stretching vibration, strong bands at 1600/cm for C=C and C=N stretching vibrations. On the other hand, the hiding of carbonyl band at 1666-1647/cm for enone system is a good exponent for the formation of C=N and the occurrence of cyclization reaction to give 2-pyrazolines (Samad, et al., 2015).

The ^{1}H-NMR spectra of pyrazolines, Fig. 4, showed characteristic signals corresponding to protons of C_2 and C_3 of 2-pyrazoline ring; a distinct ABX system proving the nonequivalence of protons at C_2. It causes to the appearance of three doublet to doublet (dd) signals at 2.87, 3.27, 4.81 ppm for H_a, H_b and H_c respectively, with two doublets at 5.86 and 6.58 ppm due to the styryl double bond confirms expected structure. Table V shows the detail of the ^{1}H-NMR data (Hussein, 2014).

The ^{13}C-NMR spectra of pyrazolines, Fig. 5 showed three signals at 40.11, 63.82 and 70.19 ppm due to the presence of C_2, C_3 of the pyrazoline ring and C_{10} of the benzyloxy group, respectively, and the other 13 peaks between 115 and 159 ppm approximately attributed to 13 types of aromatic carbon atoms.

IV. Conclusions

The results presented in this work pretend that there is a substantial improvement effect in the yield and the rate of the aldol condensation between substituted benzaldehydes and acetone forming curcumin analogs and their corresponding pyrazolines using ultrasound irradiation technique. The formation of curcumin analogs under ultrasound technique found to be inexpensive, efficient, fast, with high yields. In some cases, no results were found when using a traditional method for preparation of curcumin analogs. The results showed that solid NaOH gives better yields than an appropriate solution of NaOH as a catalyst.

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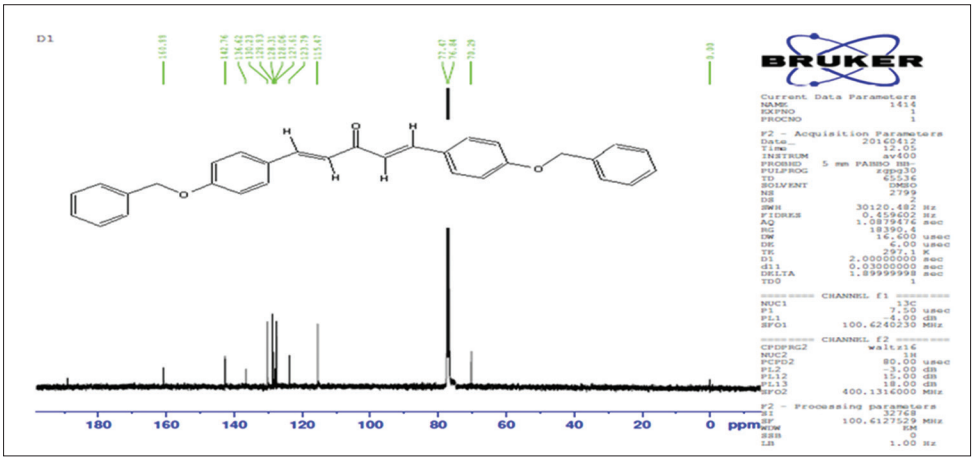

Fig. 3. ^{13}C-nuclear magnetic resonance spectrum of compound 2b.

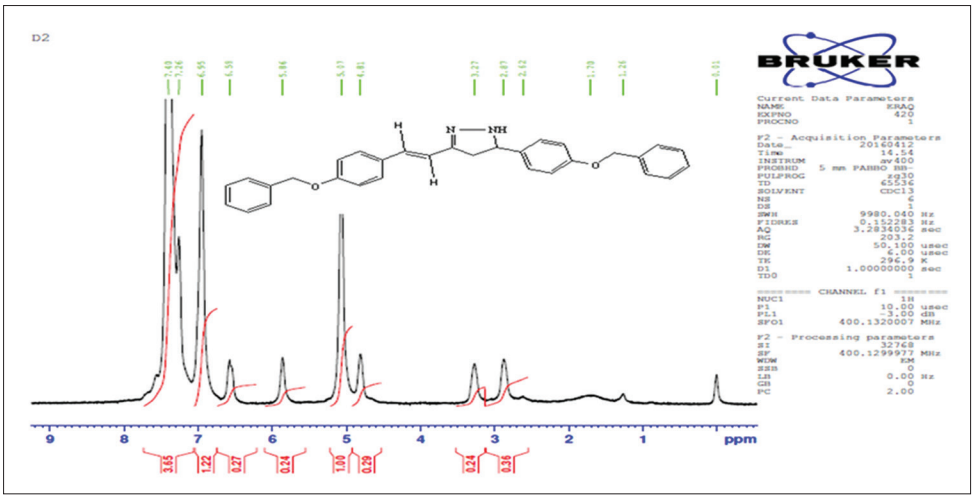

Fig. 4. ^{1}H-nuclear magnetic resonance spectrum of compound (3b).

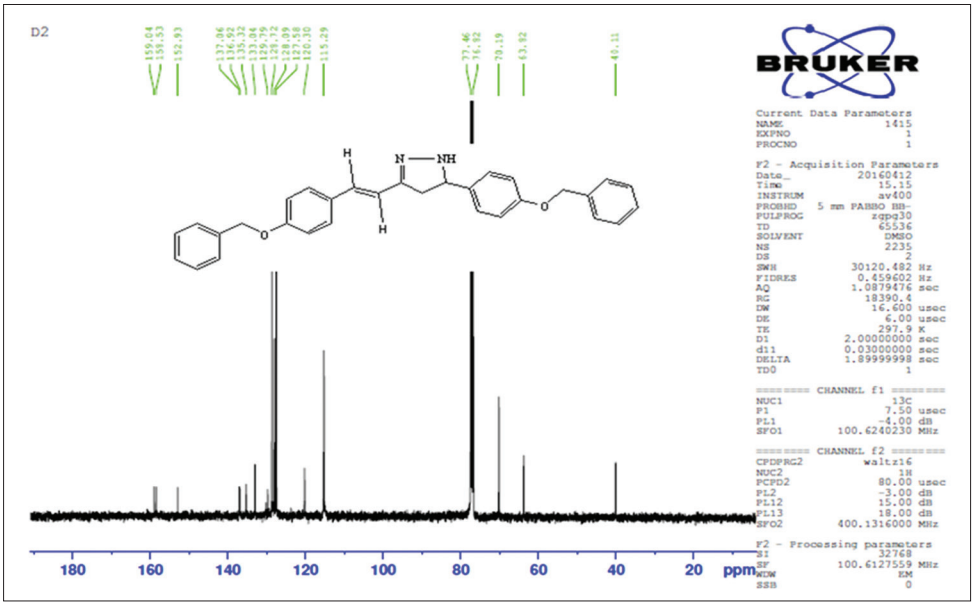

Fig. 5. ^{13}C-nuclear magnetic resonance spectrum of compound (3b).

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Prevalence of *Sarcocystis* Species (*Sarcocystis ovicanis* and *Sarcocystis capricanis*) in Tongue Muscle of Sheep and Goats in Duhok Province, Kurdistan Region, North Iraq

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***Abstract*–*Sarcocystis* species are coccidian protozoan parasites of the phylum apicomplexa. The prevalence of *Sarcocystis* species (*Sarcocystis ovicanis* and *Sarcocystis capricanis*) in tongue muscle of sheep and goats that collected from abattoir and outside of abattoir (at Butchers Markets) in Duhok province was determined for the first time during the period of 4 months from September 01, 2014, to January 03, 2015. Three techniques were applied for this purpose. Direct scotch cellophane adhesive tape test, muscle mincing and squash method, and pepsin digestion technique. The overall prevalence was 97% in sheep and 100% in goats. No significant difference (p>0.05) was obtained between male and female of both species. Histopathological analysis revealed different size and shape of microcysts with thick cyst wall, in addition to mild histological changes.**

***Index Terms*–Microcysts, *Sarcocystis* species (*Sarcocystis ovicanis* and *Sarcocystis capricanis*), Tongue muscle of sheep and goats.**

I. Introduction

Sarcocystis species are cyst forming sporozoan parasites with an obligatory 2-host cyst cycle, involving carnivorous as definitive host and herbivorous and omnivorous as intermediate hosts (Dubey, et al., 1989a). *Sarcocystis* species are common parasites with worldwide distribution in man and many species of animals. They infect skeletal muscle, cardiac muscle, and smooth muscle (Fayer, 2004). Four species of *Sarcocystis* have been identified from domestic sheep including *Sarcocystis ovicanis (Sarcocystis tenella)* and *Sarcocystis arietcanis* are pathogenic species, form microscopic cysts of sarcocystis and are transmitted through canids, as well as *Sarcocystis ovifelis (Sarcocystis gigantea*) and *Sarcocystis medusiformis*, are non-pathogenic species of *Sarcocystis*, form macroscopic cyst and are transmitted through felids (Dubey, et al., 1989b; Hosseini, et al., 2012; Hamidininejet, et al., 2012). There are three reported species of *Sarcocystis* in domestic goats; *Sarcocystis capricanis* and *Sarcocystis hircicanis* produce microscopic pathogenic and *S. caprafelis* produces macroscopic non-pathogenic cysts (Dubey, et al., 1989). Merogony and cyst formation (A sexual stage) take place in the intermediate host. Gametogony and sporogony (sexual stage) take place in the definitive host. Most pathogenic *Sarcocystis* spp. causes disease only in their intermediate hosts not in their definitive hosts (Dubey and Lindsay, 2006).

In general, the *Sarcocystis* species that are transmitted via canids or primates are more pathogenic than those transmitted by felids. In intermediate hosts, the reduction of wool quality and milk yield, abortion, central nervous system signs, and death may result (Fukuyo, et al., 2002). This paper planned on a study of prevalence and histopathological changes of *Sarcocystis* species in infected tongues of sheep and goats slaughtered inside and outside of abattoir in Duhok governorate for the first time.

II. Materials and Methods

A total of 129 muscle samples of tongues including 81 sheep (48 male and 33 female) and 48 goats (25 male and 23 female) ranged their age from 1 to 3 years old were randomly collected from slaughterhouse and those animals slaughtered at outside of the slaughterhouse (from butchers markets) during the period of 4 months from September 01, 2014, to January 03, 2015, for the first time in Duhok province. All tongues before taking samples were inspected thoroughly for revealing macroscopic cyst. A small piece of each muscle from tongue was taken and kept in a

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clean plastic tube for histopathological section and further examination of microscopic cyst of sarcocystosis.

III. Methods for Detection of Microcysts

In the Laboratory of Clinical Pathology/College of Veterinary Medicine/Duhok University, the collected samples of tongue were prepared for examination. The following examinations were done.

A. Direct Scotch Cellophane Adhesive Tape

This method was simply performed and it was a newly modified method described by Hussein (2015). About 10 cm of scotch tape on sticky surface was put on the small pieces of cut surface of tongue tissue, and firmly pressed. Then, the tape applied on a clean microscopic slide and examined under light microscope using low and high power (×10 and ×40) for revealing different sizes of tissue cysts (bradyzoites).

B. Muscle Mincing and Squash Method

A modified method which described by Juyal, et al. (1989), was used in this study. A small piece about 2 g of tongue tissue was finely teared by sterile scissor and scalpel in a clean glass watch, then after mincing it mixed with 15 ml of saline buffer pH 7.2. The obtained suspension sifted and squeezed through three layers of surgical gauze. Several small drops of suspension were examined immediately under light microscope (×10, ×40). Dry smears from suspension were prepared and fixed with methanol then stained with 7% of Giemsa stain.

C. Acid Pepsin Digestion Test

A method which described by Dubey, et al. (1989) was used. 50 g of tongue tissue was minced then added into the digested solution (1.3 g pepsin, 3.5 ml HCL, and 2.5 g NaCl in 500 ml of D.W). It thoroughly mixed and then incubated for 30 min at 40°C. The digested muscle sifted via three layers of surgical gauze to remove undigestible particles. The filtrated solution centrifuged for 5 min at 3000 rpm. The sediment samples were re-suspended by adding 5 ml of buffer saline pH 7.2. Several drops were examined under (×10, ×40) light microscope and also dry smears fixed and stained with 7% Giemsa stain were prepared.

D. Histopathological Examination

The tongue muscles were fixed in 10% of neutral buffered formalin and then dehydrated by different concentration of ethanol. They embedded in paraffin and 5 µm in thickness sections were prepared and stained with hematoxylin and eosin (H and E), Giemsa stain and periodic acid-Schiff (PAS) stains then examined under light microscope (×40) (Boncroft and Stevens, 1999).

IV. Results

No macroscopic cyst of sarcocystosis was observed in all examined tongue samples in both sheep and goats by naked eye inspection. Microscopic type of *Sarcocystis* was revealed by different techniques. The overall prevalence of sarcocystosis was 97.5% in sheep and 100% in goats which recorded in this study (Table I). No significant difference ($p>0.05$) was observed in infection rate between male of sheep 95.8% and male of goats100% and female of sheep and of goats 100%.

The sensitivity of three techniques which applied to demonstrate the microscopic cyst of sarcocystis in sheep was appeared 100% by both acid pepsin digestion and mincing and squeezing method, while it was 92% by scotch cellophane adhesive tape. In goats, the sensitivity of the three techniques was 100% (Table II).

The intensity of microcyst was estimated by the number of cysts in each microscopic field. The mean number of the intensity calculated out of 60 microscopic fields (Table III). The number was higher in sheep 33.1 cyst for each field than in the goats 16.5 cysts for each field.

The different shapes of microcysts including oval, spindle, and elliptical shape found by scotch adhesive tape and by mincing and squeezing method (Fig. 1). Typical crescent shapes of bradyzoites observed by pepsin digestion technique in both animals (Fig. 2).

TABLE I
Overall Prevalence and Distribution of Infection between Male and Female of Sheep and Goats

Sex	Sheep			Goats		
	Number of exam	Positive	%	Number of exam	Positive	%
Male	48	46	95.8	25	25	100
Female	33	33	100	23	23	100
Total	81	79	97.5	48	48	100
Overall	129					

TABLE II
The Sensitivity Rate of the Three Techniques (APD, CAT and MSM)

Animal	CAT			MSM			PDT		
	N	Positive	%	N	Positive	%	N	Positive	%
Sheep	24	22	92	41	41	100	16	16	100
Goat	13	13	100	25	25	100	10	10	100
Total	37	35	95	66	66	100	26	26	100

CAT: Cellophane adhesive test, MSM: Mincing and squash method, PD: Pepsin digestion technique

TABLE III
The Intensity Rate (Number of Cysts/Field) of Microcysts in Sheep and Goats

Animal	Tongue	
	Number of cysts/60 fields	Number of cysts/field
Sheep	1986	33.1
Goats	992	16.5

TABLE IV
The Size of Microcysts (Mean±SD) of Tongue in Sheep and Goats

Animal	Number of cysts examined	Mean±SD	
		Length	Wedth
Sheep	65	12.9±1.4	7.4±0.7
Goats	65	11.3±1.2	7.2±0.8

SD: Standard deviation

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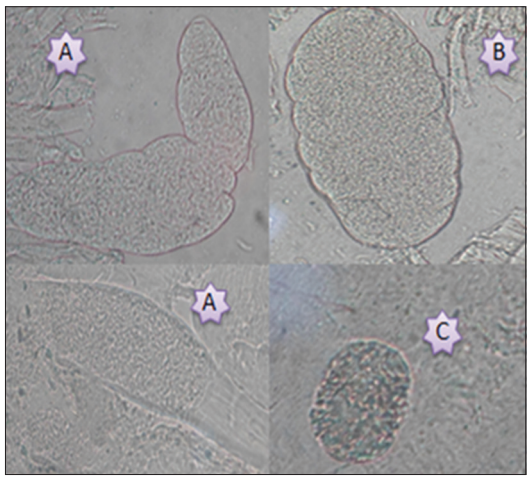

Fig. 1. Scotch adhesive tape method. (A) Spindle cyst, (B) elliptical cyst, (C) rounded cyst

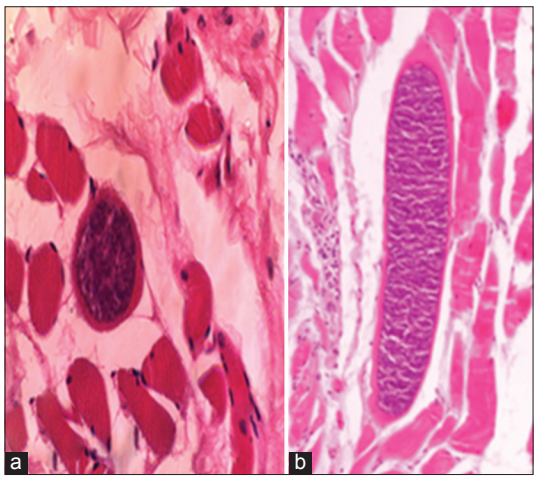

Fig. 3. Histopathological sections. (a) Oval shape, (b) spindle shape of microcysts (×40)

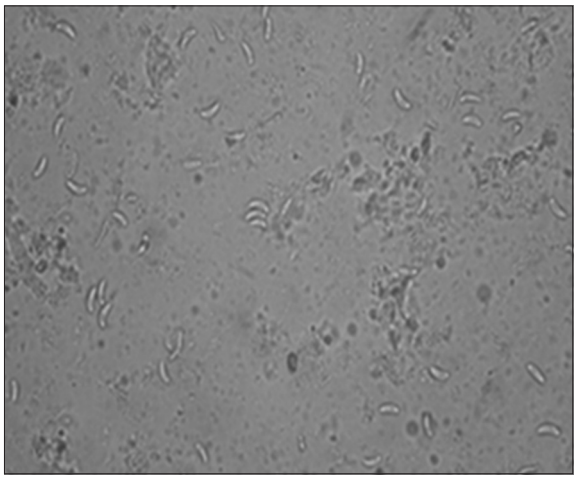

Fig. 2. Crescent shape of bradyzoites by peptic digestion and Giemsa staining (×40)

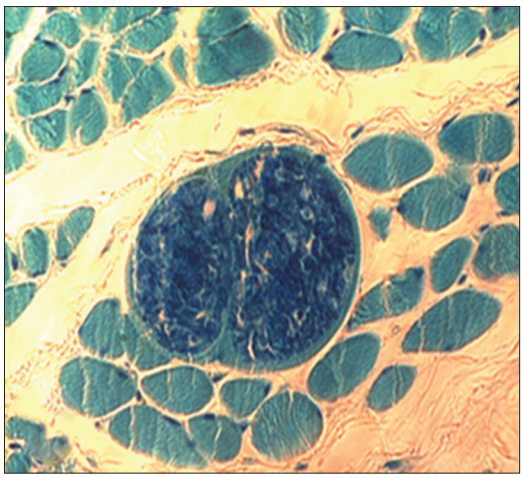

Fig. 4. Microcyst impacted with bradyzoites stained by giemsa (×40)

The size of microcyst was measured using ocular micrometer. There was no statistically difference ($p>0.05$) in mean±standard deviation (SD) of length and width of cysts in both sheep and goats. The measurement size of cysts was 12.9±1.4 µm in length and 7.4±0.7 µm in width in sheep, while the length 11.3±1.2 µm and the width 7.2±0.8 µm of cysts was in goats (Table IV).

Histologically, high intensity of different shape and size of cysts were found between muscle fibers of tongue by H and E technique (Fig. 3). The intact cysts were impacted with numerous bradyzoites seen by giemsa technique (Fig. 4). Obvious degenerated muscle fibers surrounded the tissue cysts with slightly infiltration of mononuclear cells were seen in Fig. 5. The intact thick wall around the cysts was positively stained with PAS technique (Fig. 6).

V. Discussion

Sarcocystis occurs either as microscopic or macroscopic cyst in striated muscles and sometimes in non-striated muscles (Dubey, et al., 1983). Through inspection of all tongues, no macrocyst was observed in this survey. Similarly, no data recorded the presence of macroscopic cyst in tongue, while this type of cyst prevalent on esophagus and diaphragm of several animals. Beyazit et al. (2007) recorded the highest prevalence of macrocyst in esophagus in all age groups of sheep and goats in Turkey, and also Barham et al. (2004) found the highest rate of infection 99% in esophagus and lowest rate 3% in diaphragm of goats in Sulimania province. Latif, et al. (1999) found the rate of 4.1% and 33.6% in goats and sheep, respectively, in Baghdad region. In Duhok province, Hussein (2015) found the rate 1.2% and 2.6% in sheep and goats, respectively. Another type of *Sarcocystis* (microscopic cyst) was revealed in a high frequency in the tongues in this study. The rate of infection was 100% in goats and 97.5% in sheep. This high prevalence may have diversity with definitive host (dogs) and sporocysts contamination of water and food. Furthermore, various studies were reported the presence of microscopic cysts in organs of different animals mainly tongues. Morsy, et al. (2011) found the infection rate of microcyst 43% in Egyptian goats tongue. Dafedar, et al. (2008) found the prevalence rate 12.5% in tongue of goats in Bangalor, Karnataka state. Various diagnostic methods

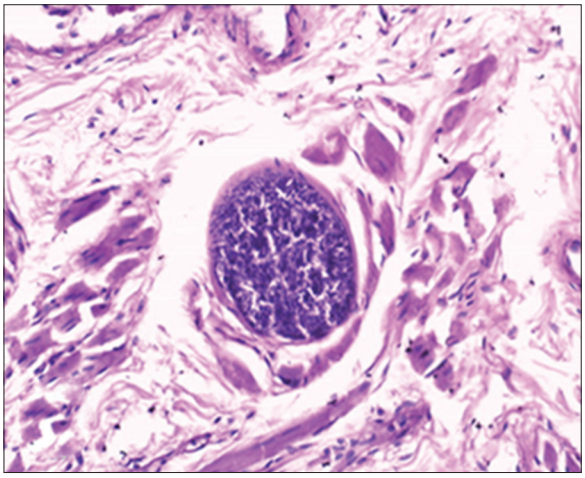

Fig. 5. Degenerated muscle fibers with mononuclear cells infiltration

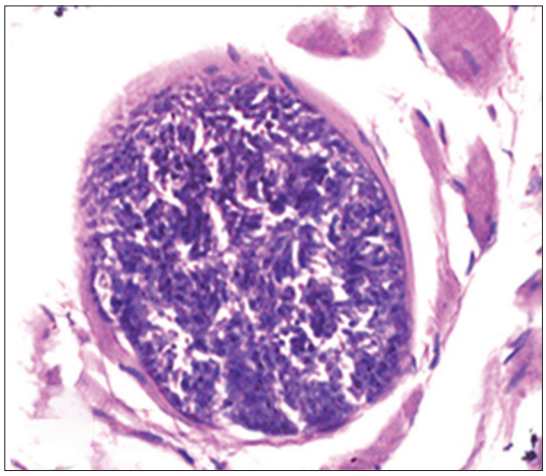

Fig. 6. Thick wall microcyst between muscle fiber stained with periodic acid-Schiff (×40)

were used for detection of sarcosporidiosis, which were had variability in sensitivity (Dubey, et al., 1988; Beyazit, et al., 2007). By pepsin digestion and muscle squash preparation, the high prevalence of microcyst was found 100%; this may be due to validity and reliability of these two tests; therefore, they considered as the gold standard tests in diagnosis of bradyzoites of sarcocystosis. Similar result was recorded by Dehaghi, et al. (2011), who found the prevalence of microcyst in goats 98% by impression smear and 100% by acid digestion technique. Histologically, analysis was revealed thick wall of microcyst in different intensity and in shapes with mild inflammatory infiltration. This indicated the presence of microcysts which is the most visible type by the procedures in chronic condition.

VI. Conclusion

This study considered the tongue of animals as a good sample in demonstration of microscopic cyst of *Sarcocystis* species in sheep and goats. The cellophane adhesive tape was a newly developed technique used in this study. It was simple, rapid and inexpensive but its sensitivity was lower than peptic digestion which considered as a golden standard test. There was no significant difference in the prevalence of sarcocystosis among intensity, measurement size and cell wall of microcysts between tongues in sheep and goats. For the first time, the estimation of intensity of infection (cysts/field) and measurement size of microcysts after staining with 7% giemsa was used in this study. Depending on the morphology, two suspected species of *Sarcocystis* were found including; *S. ovicanis* (*Sarcocystis tenella*) in sheep and *Sarcocystis capracanis* in goats which produce microscopic cysts of sarcocyst.

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